101. Poisson's ratio is typically used in:

(A) heat transfer

(B) HVAC

(C) mechanical behavior

(D) vapor power cycles

102. Which of the following is used as a measure of energy efficiency of refrigeration systems?

(A) COP

(B) Carnot efficiency

(C) Latent heat

(D) SHR

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103. A system with an initial cost of $90,000 has an operating cost of $2.50/hr and is operated 16 hr/day for 300 days/year. After 10 years, the system has a salvage value of $10,000. Assuming the interest rate is constant at 10%, the total annualized cost over the 10-year life is most nearly:

(A) $12,000
(B) $14,000
(C) $20,000
(D) $26,000

104. A machining operation creates a hole for a 3/8-16NC × 0.75-in.-long countersink head screw, as shown in **Figure 1**. A cutter is used to create the countersink recess as shown in **Figure 2**. The process steps are as follows:

1. Drill through with a tap drill diameter of 5/16 in.
2. Countersink the tap drill hole to a depth of Dimension A, so that the screw head will be flush with the part surface.
3. Tap the hole 3/8-16NC.

To complete Step 2, the depth (in.) of Dimension A is most nearly:

(A) 0.202
(B) 0.234
(C) 0.269
(D) 0.313

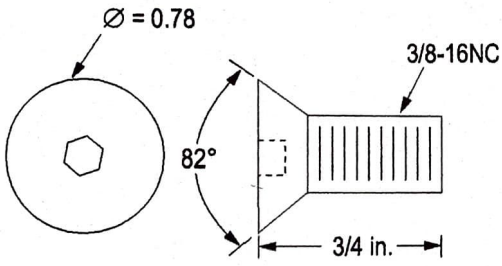

FIGURE 1

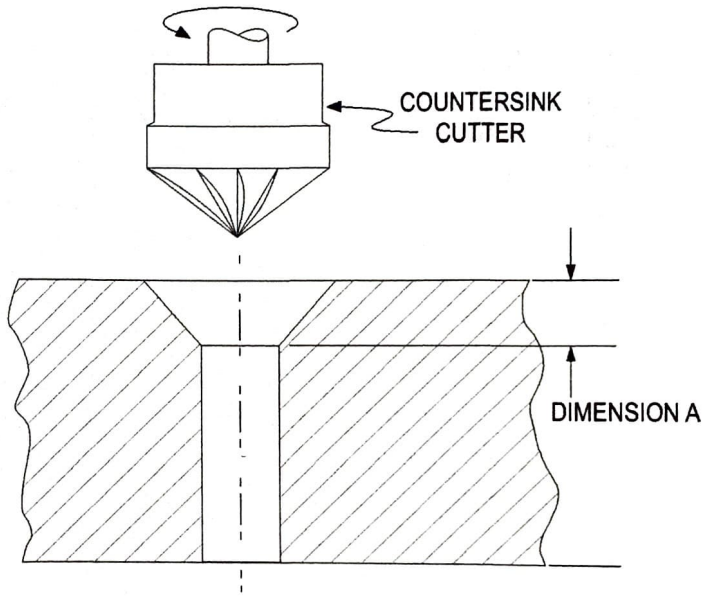

FIGURE 2

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105. A commercial product is sold in 55-gal drums. The product mixture consists of inert ingredients, to which an active ingredient is added. The active ingredient can be purchased in two different formulations as shown.

Formulation	Cost/lb	Active Ingredient (units/lb)
1	\$8	100
2	\$10	200

The amount of Formulation 1 used per drum cannot exceed 3 lb, and the amount of Formulation 2 used per drum cannot exceed 2 lb. The total cost for the active ingredient cannot exceed \$36/drum. The largest number of units of active ingredient that can be added per drum under these constraints is most nearly:

(A) 400
(B) 540
(C) 600
(D) 700

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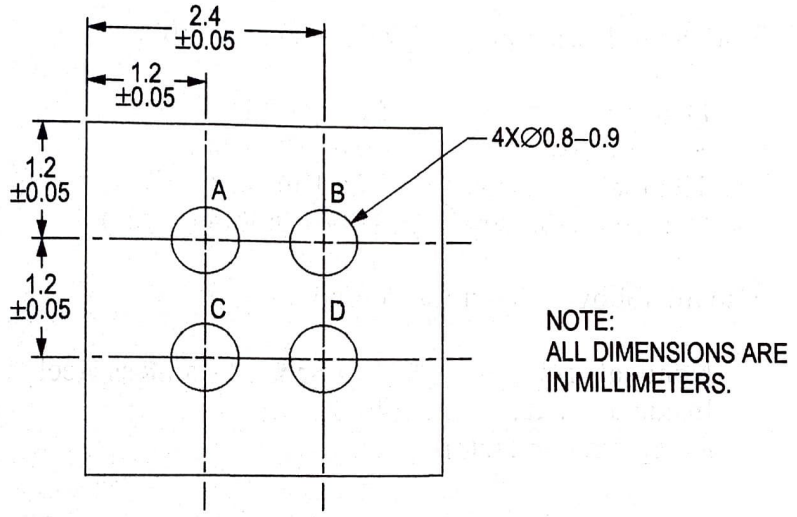
106. Referring to the figure, the minimum material thickness (mm) between Holes A and B is most nearly:

(A) 0.2
(B) 0.3
(C) 0.4
(D) 0.5



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107. A solar-thermal power system pumps and stores hot (1,000°F) liquid sodium in an insulated overhead storage tank, as shown in the figure. The pump delivers sodium at the rate of 50 lbm/sec.

Use the following properties of sodium at 1,000°F:

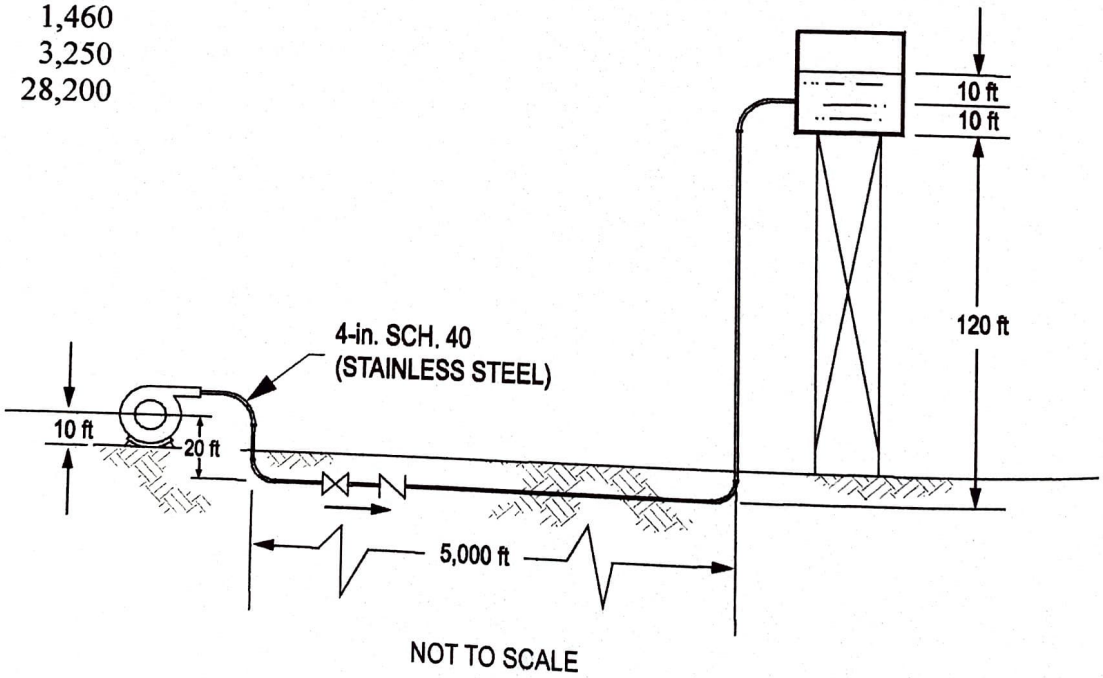
Density	51.4 lbm/ft^3
Specific heat	0.301 Btu/(lbm-°F)
Thermal conductivity	37.6 Btu/(hr-ft-°F)
Dynamic viscosity	0.000156 lbm/(ft-sec)

Use the following data for the sodium pipe:

Nominal size	4-in Sch. 40 stainless steel
Inside diameter	4.026 in.
Darcy friction factor	0.01

The convective heat-transfer coefficient [Btu/(hr-ft^2-°F)] at the inside surface of the pipe is most nearly:

(A) 275
(B) 1,460
(C) 3,250
(D) 28,200



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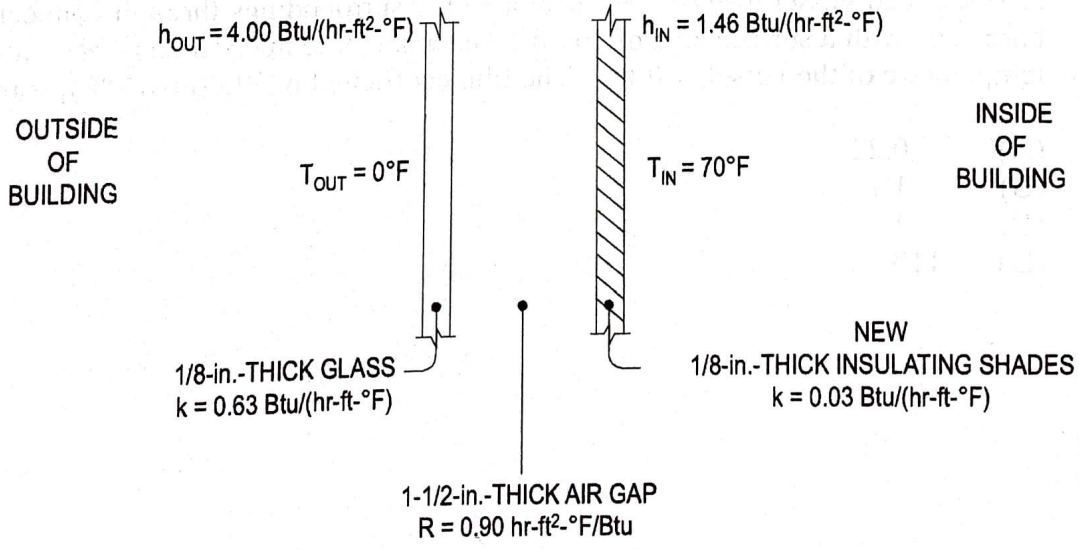
108. A 6.0-in. O.D. tube with a wall thickness of 0.10 in. and an axial length of 20 ft is located in a roofed building. The temperature of the ambient air is 65°F, and the convective heat-transfer coefficient is 5.0 Btu/(hr-ft^2-°F).

The outer surface temperature of the pipe is 450°F. The emissivity for the pipe is 0.5. The total rate of heat loss (Btu/hr) is most nearly:

(A) 93,000
(B) 77,000
(C) 62,000
(D) 16,000

109. To save on heating costs, a business is considering adding insulating shades to the 200 ft^2 of single-pane windows in its historic office building, as shown in the figure. Neglecting radiation, the reduction in heat loss (Btu/hr) that would be achieved by adding the shades is most nearly:

(A) 11,200
(B) 8,300
(C) 6,400
(D) 300



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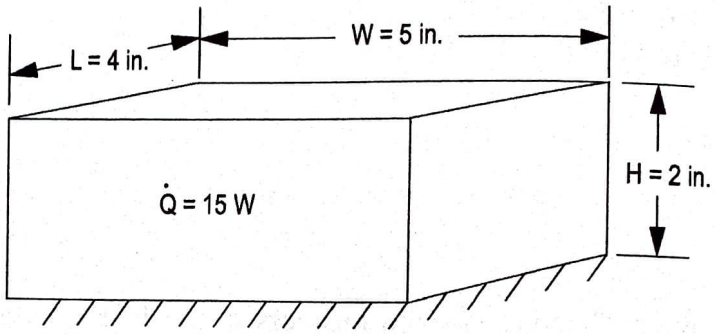
110. An electronic component (see figure) is mounted adiabatically at its base. The component dissipates 15 W, and the ambient air and surroundings are at 75°F.

Assuming a constant heat flux, an average radiative heat-transfer coefficient ($h_{radiation}$) of 1.00 Btu/(hr-ft^2-°F), and an average convective heat-transfer coefficient ($h_{convection}$) of 1.25 Btu/(hr-ft^2-°F), the surface temperature of the component is most nearly:

(A) 118°F
(B) 133°F
(C) 180°F
(D) 206°F



ADIABATIC MOUNTING BASE

111. A suspended vessel loses 45,000 Btu/hr to the surroundings through convection. The vessel is bare steel with a surface area of 400 ft^2. The ambient temperature is steady at 75°F. The surface temperature of the vessel is 100°F. The film coefficient h [Btu/(hr-ft^2-°F)] is most nearly:

(A) 0.22
(B) 1.1
(C) 4.5
(D) 110

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112. An insulated panel box containing electrical equipment will be located outdoors. The equipment will generate 500 W of heat. The following information is given:

Insulation thickness	1/2 in.
Insulation thermal conductivity	0.03 Btu/(hr-ft-°F)
Heat-transfer coefficient	5 Btu/(ft^2-hr-°F)
Surface area of panel box	100 ft^2

If the outdoor temperature is 100°F, the temperature expected inside the box is most nearly:

(A) 70°F
(B) 130°F
(C) 200°F
(D) 387°F

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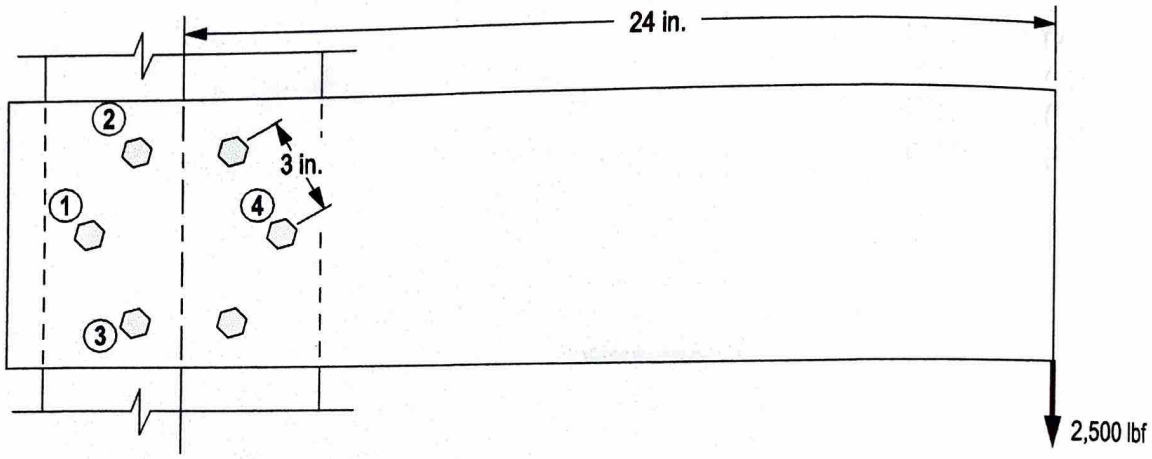
113. The 2,500-lbf load shown in the figure is supported by a beam that is secured by six 3/4-in. diameter bolts in a hexagonal array with neighboring bolts 3 in. apart. The shear stress is greatest in which bolt?

(A) 1
(B) 2
(C) 3
(D) 4



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114. Water (100 lbm/min, 60°F) and steam (100 lbm/min, 600°F), both at slightly above atmospheric pressure, enter an insulated chamber through separate inlets. After thorough mixing, 200 lbm/min of the product is withdrawn at atmospheric pressure. The quality of the steam in the product stream is most nearly:

(A) 0.12
(B) 0.43
(C) 0.52
(D) 0.60

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115. Consider the following stoichiometric reaction:

$$C_9H_{18} + 13.5\ O_2 + 50.8\ N_2 \rightarrow 9\ CO_2 + 9\ H_2O + 50.8\ N_2$$

The mass fraction of water in the flue gas is most nearly:

(A) 5.8%
(B) 8.2%
(C) 10.7%
(D) 13.1%

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116. Steam (600°F, 300 psia) is expanded in an 80% adiabatic efficiency turbine to 3 psia. The enthalpy (Btu/lbm) of the resulting 3-psia steam is most nearly:

(A) 880
(B) 970
(C) 1,040
(D) 1,120

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117. An automotive air-conditioning system based on R-134a operates between 250 psia and 40 psia. A pressure-enthalpy diagram for R-134a is shown on the opposite page. If 250-psia saturated liquid R-134a is throttled to 40 psia, the change [Btu/(lbm-°R)] in entropy ($S_{final} - S_{initial}$) will be most nearly:

(A) –0.07
(B) 0.01
(C) 0.11
(D) 0.15

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117. (Continued)

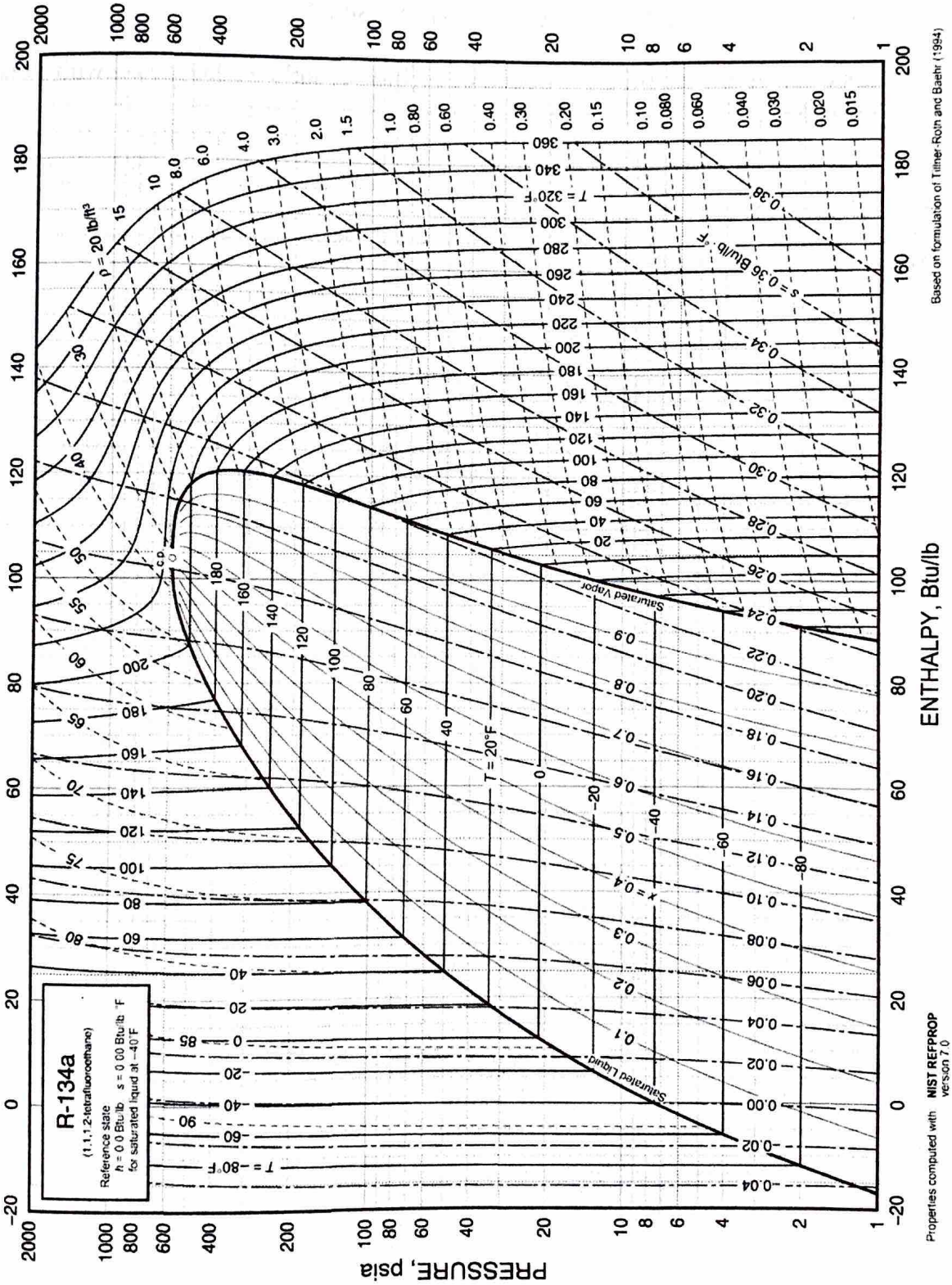

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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118. Fuel is burned in a furnace with 12% excess air to minimize the formation of partially oxidized product. The average molecular weight of the fuel is 126. The overall complete **stoichiometric** combustion reaction is:

$$C_9H_{18} + 13.5\ O_2 + 50.8\ N_2 \rightarrow 9\ CO_2 + 9\ H_2O + 50.8\ N_2$$

The mass of air (lbm) required per pound of fuel for complete combustion with 12% excess air is most nearly:

(A) 3.8
(B) 14.8
(C) 16.5
(D) 18.3

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119. A direct-pumped variable-flow chilled water system, serving three air handlers in a building, is shown in the flow schematic. AHU-3 and the system bypass are located 75 ft above the main mechanical room housing the chiller and pump.

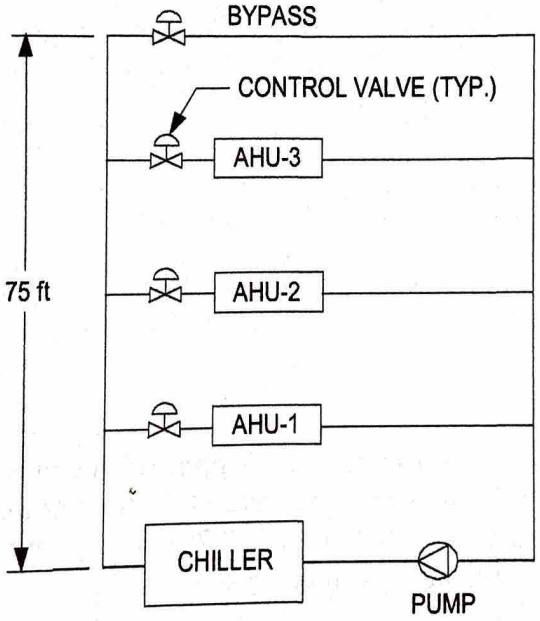
Chiller selected for:
500 gpm, 10° ΔT
20 ft of head evaporator pressure drop

Each AHU is selected for:
12° ΔT, 150 gpm, 10 ft of head pressure drop.

The control valves are selected for a maximum 5-psi pressure drop at the design flow rate.

For proper system operation, the minimum required differential pressure (psi) between the chilled water supply and return headers measured at the chilled water bypass is most nearly:

(A) 80
(B) 45
(C) 35
(D) 10



NOT TO SCALE

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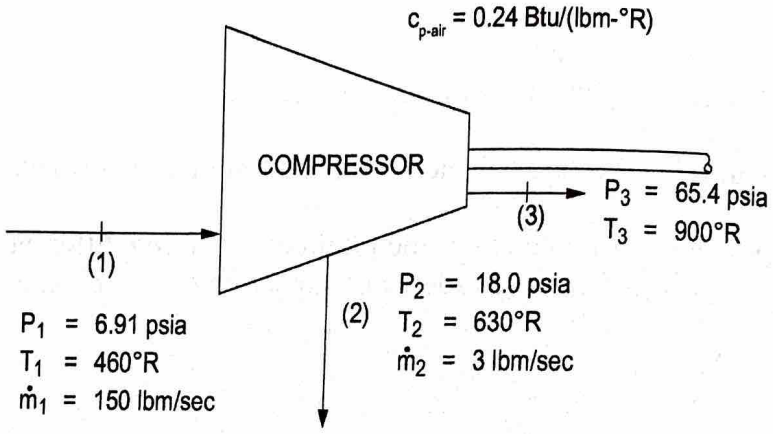
120. Below is a schematic diagram of the compressor of an aircraft gas turbine. A portion of the air that enters at State 1 is extracted at State 2, cooled, and then expanded in a turbine to be used for cabin pressurization. The balance of the air leaves at State 3. Known properties (stagnation pressures and temperatures) and other data are given with the diagram. The power (hp) required to drive the compressor is most nearly:

(A) 370
(B) 15,900
(C) 16,500
(D) 22,100



121. A centrifugal pump is used to transport 25 gpm of acetone at 78°F. The differential pressure across the pump is 50 psi. The vapor pressure of acetone at this temperature is 5.6 psia, viscosity is 0.3 cP, and density is 49 lbm/ft^3 (sp gr = 0.79). The pump efficiency is 70%. The input shaft horsepower (hp) to drive the pump is most nearly:

(A) 0.12
(B) 0.73
(C) 1.04
(D) 1.35

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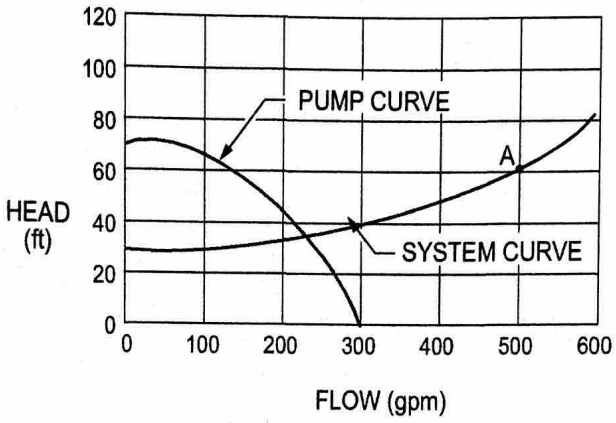
122. Given a hydronic piping system and a number of pumps, each having performance characteristics as shown in the figure, the **minimum** number of available pumps needed to supply the required flow at system operation Point A is:

(A) two

(B) three

(C) four

(D) Cannot be done with the available pumps



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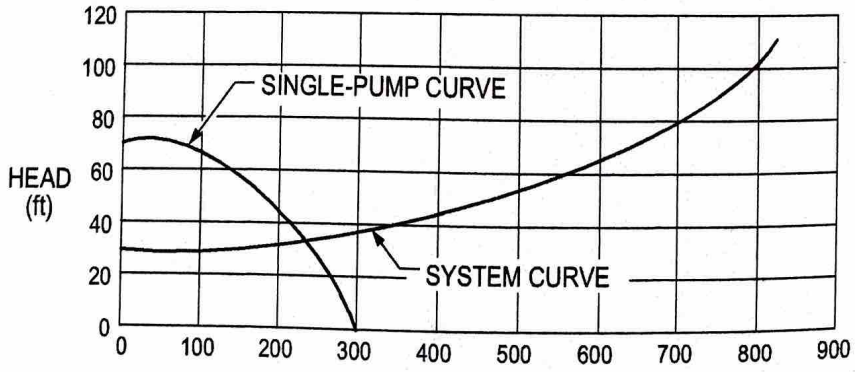
123. A centrifugal pump is sized to deliver 200 gpm at a head of 60 ft of water. It is operating at 1,750 rpm. The pump efficiency is 75%. When the speed of the pump has been reduced to 1,000 rpm, the head (ft of water) is most nearly:

(A) 8.5
(B) 11
(C) 20
(D) 34

124. A piping system includes three pumps, each having the performance characteristics shown in the graph. The supply head (ft) that three pumps operating in parallel will deliver to this hydronic system is most nearly:

(A) 210
(B) 65
(C) 38
(D) 30



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125. A centrifugal pump is sized to deliver 200 gpm of water at 60°F against a head of 60 ft of water. It is operating at 1,750 rpm. The pump efficiency is 0.75, and the motor efficiency is 0.83. If the electricity cost is $0.06/kWh, the electrical cost to operate the pump 8,000 hr/yr is most nearly:

(A) $984
(B) $1,086
(C) $1,200
(D) $1,750

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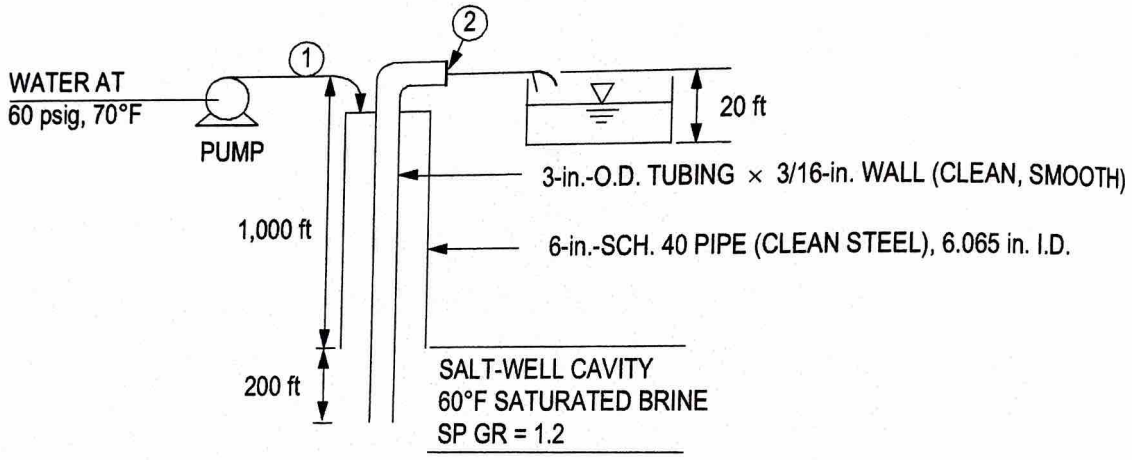
126. A salt-well cavity is 1,000 ft below grade. The cavity is filled with sodium chloride brine at 60°F. The well casing is 6-in. Sch. 40 pipe. There is an inner tube of 3-in. O.D. × 3/16-in. wall. Water at 70°F is pumped into the cavity through the annular space, displacing the brine and forcing it to surface through the inner tube into a storage tank. The brine discharge rate is 50 gpm. Neglecting velocity change, if the total friction head is 25 ft of water and the net static head ($h_2 - h_1$) is 225 ft of water, the pump power (hp) needed to transfer 50 gpm of brine is most nearly:

(A) 1.34
(B) 2.53
(C) 3.16
(D) 10.50



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127. A nuclear reactor is housed in a leak-tight containment building. The building is designed to withstand the pressure and temperature resulting from an accidental breach of the pressure boundary of the reactor. During normal operating conditions, the reactor, which has a void volume of 9,000 ft^3, contains helium at 1,000 psia and 1,340°F. The containment building normally contains air at 14.65 psia and 140°F. Use 0°R as the reference temperature for calculating thermal properties.

Property	Helium	Air
c_p, Btu/(lbm-°F)	1.24	0.241
c_v, Btu/(lbm-°F)	0.745	0.172
k	1.667	1.400
M, lbm/(lb mol)	4	29

In an accident, helium from the reactor slowly leaks into the building. The operating crew of the plant is able to plug the leak before equilibrium pressure is reached. At this state, it is determined that the helium mass fraction in the building is 0.09091 and the building pressure is 30 psia (building air mass is 15,000 lbm). The mass (lbm) of helium released into the building is most nearly:

(A) 1,364
(B) 1,500
(C) 1,650
(D) 1,800

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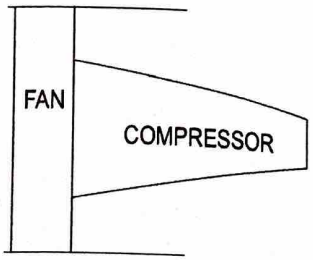
128. A turbofan engine is operating on a test stand at sea level with an ambient temperature of 80°F and an ambient pressure of 14.7 psia. Known data for the fan-compressor portion are provided in the figure. The input power (hp) required to drive the combined fan-compressor is most nearly:

(A) 19,400
(B) 26,800
(C) 87,100
(D) 112,000

Compressor mass rate of flow	100 lbm/sec
Fan mass rate of flow	400 lbm/sec
Compressor pressure ratio	10
Fan pressure ratio	1.3
Fan and compressor efficiencies	85%
K	1.4
c_p	0.24 Btu/(lbm-°R)



129. Air with the following properties enters the compressor of an aircraft gas turbine.

P = 5.45 psia
T = 430°R
V = 600 fps
$\dot{m}$ = 150 lbm/sec

The cross-sectional area (ft^2) at the inlet is most nearly:

(A) 1.64
(B) 2.70
(C) 3.27
(D) 7.30

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130. A pitot tube measurement at a point that represents the average velocity indicates a head of 3 in. of water for air ($\rho = 0.075$ lbm/ft^3) flowing in a circular duct with a diameter of 12 in. The volumetric flow rate (cfm) of air is most nearly:

(A) 1,725
(B) 3,860
(C) 5,450
(D) 18,900

131. A centrifugal pump is operated at 3,500 rpm to produce a flow of 50 gpm. The pump speed (rpm) required to produce a flow of 60 gpm is most nearly:

(A) 2,920
(B) 3,830
(C) 4,200
(D) 5,040

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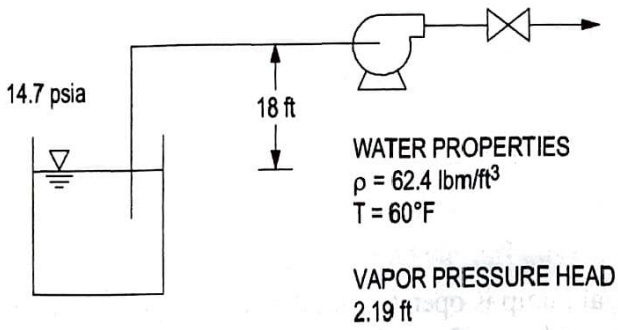
132. A centrifugal pump is sized to deliver 200 gpm of liquid with a specific gravity of 0.7 and a total differential head of 60 ft of water. The hydraulic horsepower required is most nearly:

(A) 2.1
(B) 2.7
(C) 3.0
(D) 4.3

133. The net positive suction head available for the system shown is 8 ft of water. The frictional head loss (ft) is most nearly:

(A) 6
(B) 14
(C) 24
(D) 42



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134. A constant volume HVAC system with a design flow of 11,500 cfm is to be designed with 3,000 cfm of outside air flow and the following parameters:

Design indoor conditions:
$T = 75°F$
$\phi = 50\%$

Design outdoor conditions:
$T = 40°F$
$\phi = 60\%$

The design mixed-air temperature is most nearly:

(A) 50°F
(B) 56°F
(C) 60°F
(D) 66°F

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135. For a given set of fixed steam conditions ($\dot{m}$, P, T) at the inlet to the high-pressure turbine of a fossil fuel-fired steam power plant with reheat between sections of a two-stage turbine, which of the following is a result of adding reheat?

(A) Increased moisture content at the exit from the low-pressure turbine

(B) Decreased net power output

(C) Decreased amount of energy exchanged in the condenser

(D) Increased CO_2 emissions

136. The psychrometric processes for air supplied to an auditorium are represented as Lines A and B on the accompanying psychrometric chart. Line A is the room load line, and Line B is the coil load line. The coil apparatus dew-point temperature is most nearly:

(A) 50°F
(B) 53°F
(C) 58°F
(D) 63°F

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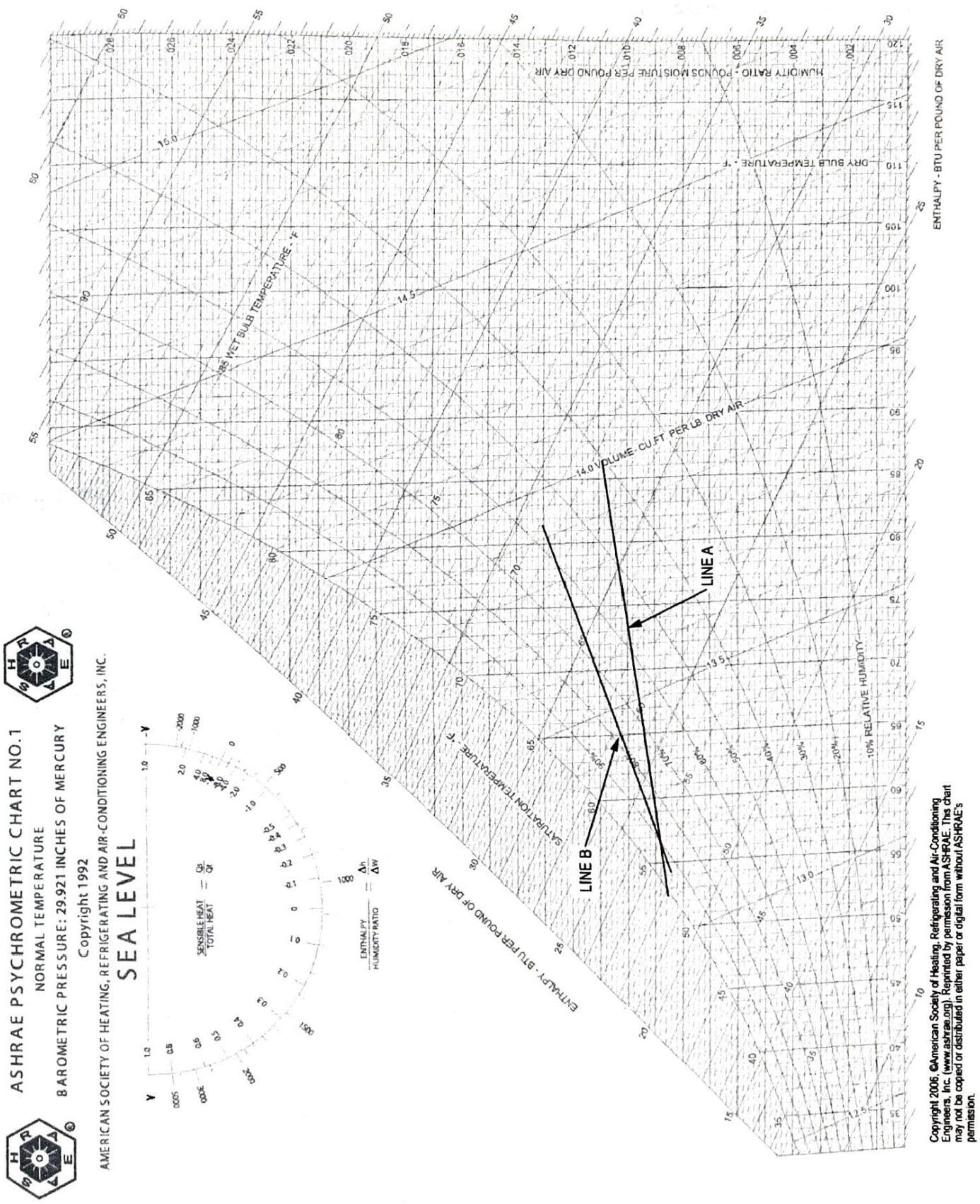
136. (Continued)


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE: 29.921 INCHES OF MERCURY
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AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
DRY BULB TEMPERATURE - °F
ENTHALPY - BTU PER POUND OF DRY AIR
WET BULB TEMPERATURE - °F
VOLUME - CU.FT PER LB DRY AIR
SATURATION TEMPERATURE - °F
ENTHALPY - BTU PER POUND OF DRY AIR
10% RELATIVE HUMIDITY
LINE A
LINE B
SENSIBLE HEAT / TOTAL HEAT = qs/qt
ENTHALPY / HUMIDITY RATIO = Δh/Δw

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137. A refrigeration system with a capacity of 1 refrigeration ton has a compressor work of 1 kW. The coefficient of performance of the system is most nearly:

(A) 0.3
(B) 1
(C) 3.5
(D) 12

138. An expansion valve would be used in which portion of the refrigeration cycle shown in the figure?

(A) A–B
(B) B–C
(C) C–D
(D) D–A

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138. (Continued)

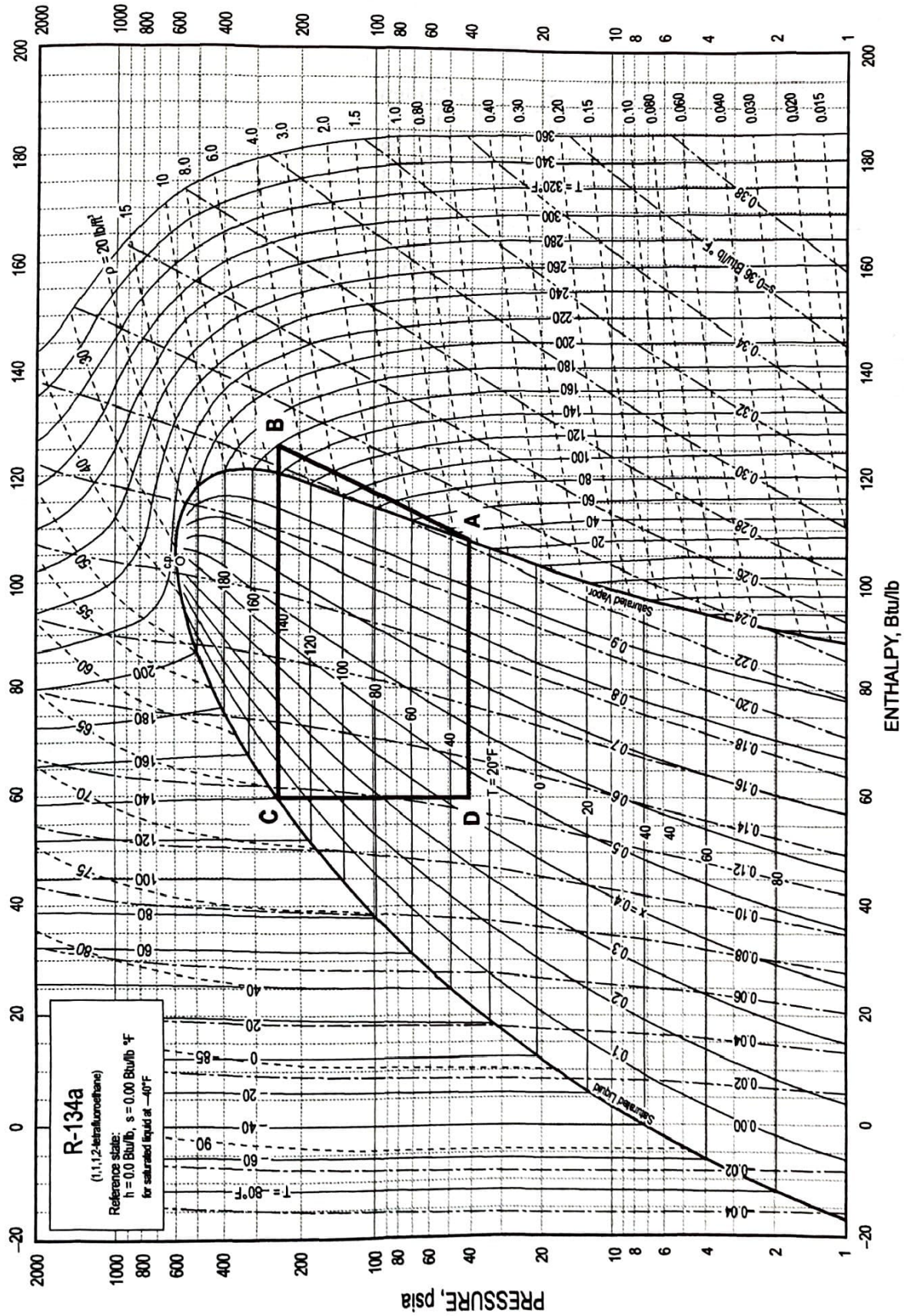

Fig. 8 Pressure-Enthalpy Diagram for Refrigerant 134a

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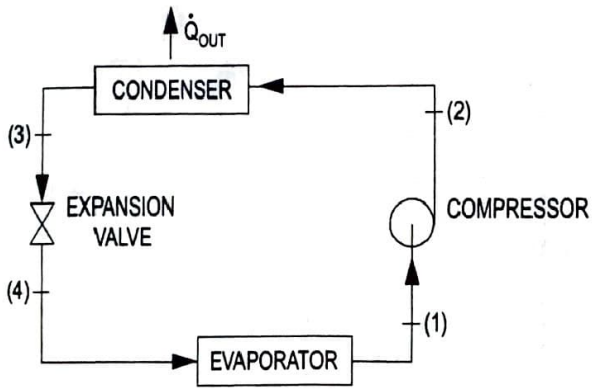
139. Known data for a vapor-compression heat pump using R-134a as the working fluid are shown in the table and figure below.

State	P (psia)	T (°F)	h (Btu/lbm)
1	16.674	−10	100.29
2	160	160	129.78
3	160	109.56	47.65
4	16.674	−10	

The coefficient of performance for this heat pump is most nearly:

(A) 1.00
(B) 1.56
(C) 1.79
(D) 2.79



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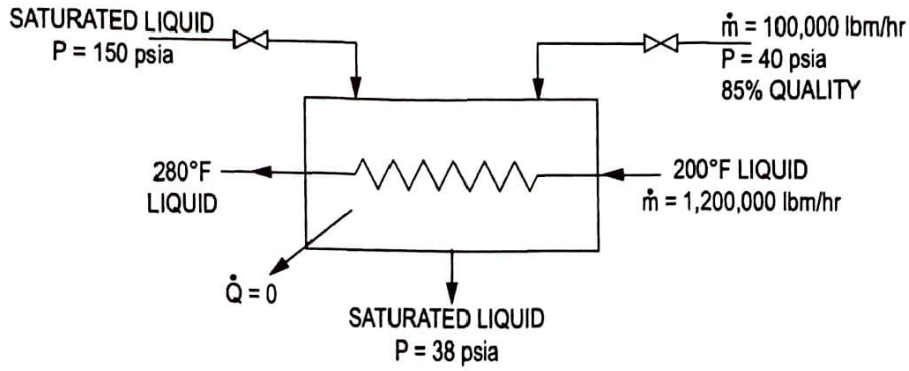
140. In the cascading feedwater heater with data shown in the figure, all working fluids are water. The outgoing saturated liquid flow (lbm/hr) is most nearly:

(A) 280,000
(B) 180,000
(C) 137,000
(D) 37,000



This completes the morning session. Solutions begin on page 69.

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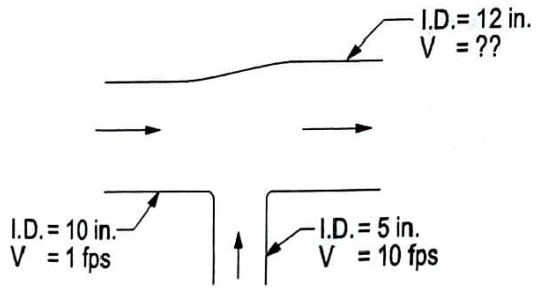
501. The Mach number just upstream of a normal shock wave in air (k = 1.4) is 4.5. The Mach number downstream of the normal shock wave is most nearly:

(A) 0.42
(B) 1.00
(C) 2.00
(D) 4.50

502. The figure shows water that flows in from two pipes and exits from a third pipe. The velocity of flow (fps) in the 12-in.-I.D. pipe is most nearly:

(A) 1.9
(B) 2.4
(C) 3.1
(D) 4.2



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503. A fluid with a specific gravity of 0.8 and a kinematic viscosity of 1.5 centistokes (1 centistoke = 1.0764×10^{-5} ft^2/sec) flows through a 4-in. I.D. hose at 5 ft/sec. The Reynolds number for this flow is most nearly:

(A) 1.2×10^6

(B) 1.0×10^6

(C) 1.0×10^5

(D) 8.3×10^4

504. A centrifugal pump operating at 1,750 rpm requires 1,000 hp. If the speed of the pump is reduced to 1,000 rpm, the power requirement (kW) will be most nearly:

(A) 426

(B) 243

(C) 187

(D) 139

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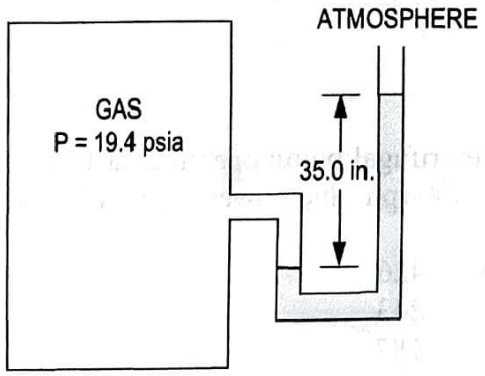
505. Water at 60°F flows through a 1-in brass pipe (1.063 in. I.D.) at 5 fps. The Moody friction factor is 0.025. The pressure drop (psi) over a 100-ft length of this pipe is most nearly:

(A) 0.40
(B) 4.8
(C) 13
(D) 150

506. A U-tube manometer containing an unknown fluid is connected to a tank containing a gas. The tank pressure is 19.4 psia, and atmospheric pressure is 14.7 psia. If the fluid height in the manometer is 35.0 in., the density (lbm/ft^3) of the manometer fluid is most nearly:

(A) 1.6
(B) 19
(C) 62
(D) 230



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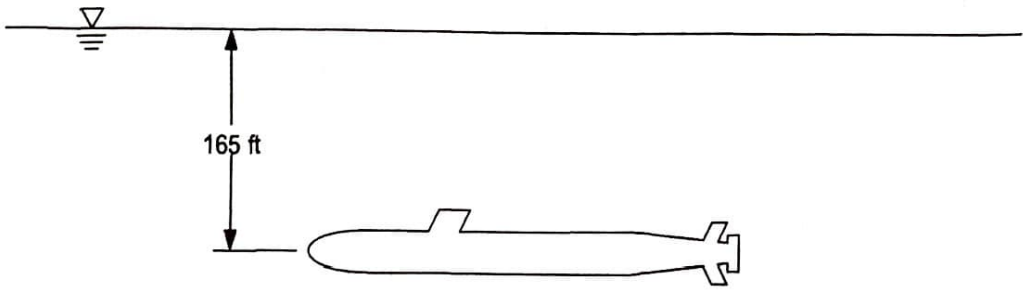
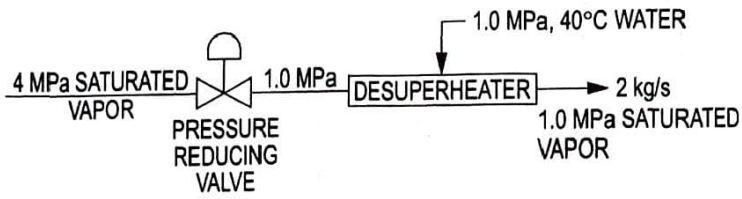
507. A submarine is traveling straight and level at a speed of 30 knots. The stagnation point of the bow is at a depth of 165 ft. Assuming the specific gravity of seawater is 1.03 and the ocean water is not moving, the pressure (psig) at the stagnation point is most nearly:

(A) 73.6
(B) 80.0
(C) 88.8
(D) 91.4



508. A steam pressure reducing valve is followed by a desuperheater. The saturated steam enters the system at 4.0 MPa and leaves the desuperheater as saturated steam at 1.0 MPa at a flow rate of 2 kg/s. Water enters the desuperheater at 1.0 MPa, 40°C to mix with the superheated steam. The flow rate (kg/s) of water to this system is most nearly:

(A) 0.009
(B) 0.012
(C) 0.017
(D) 0.023



509. A plant has a raw water demand of 21 gpm. The incoming raw water hardness expressed as $CaCO_3$ is 25 grains per gallon. Synthetic zeolite water softener has a capacity of 20,000 grains/ft^3. If the water hardness must be reduced to 2 grains per gallon, then the smallest synthetic zeolite water softener capable of meeting this need for a full 12-hour shift without regeneration has a volume (ft^3) that is most nearly:

(A) 4.5
(B) 9.0
(C) 18.0
(D) 36.0

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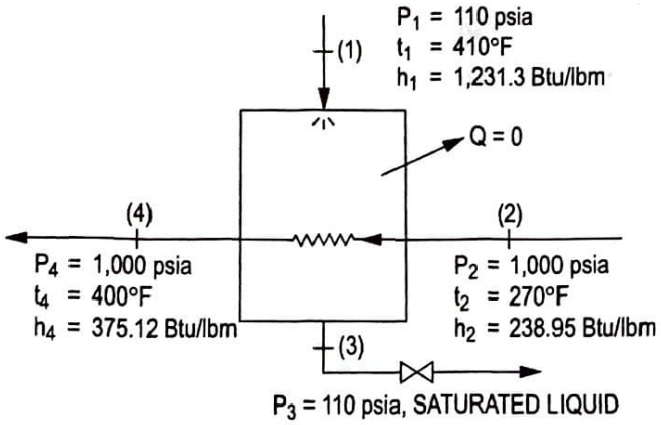
510. Known data for a closed feedwater heater are shown with the figure. The mass flow rate (lbm/min) at Point 1 for a flow rate of 60,000 lbm/min at Point 4 is most nearly:

(A) 4,200
(B) 8,800
(C) 20,000
(D) 410,000



511. Based on the psychrometric chart provided on page 111, air at a dry-bulb temperature of 95°F and 25% rh has a dew point of most nearly:

(A) 38°F
(B) 54°F
(C) 68°F
(D) 82°F

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512. A room contains equipment that consumes 3,000 W of power. In addition, 5 lbm/hr of water vapor is released into the room. The resulting cooling load (Btu/hr) is most nearly:

(A) 3,000
(B) 4,500
(C) 10,000
(D) 15,000

513. The partial pressure (psi) of water in sea level air at 80°F and 60% rh is most nearly:

(A) 0.014
(B) 0.30
(C) 0.35
(D) 0.50

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514. The pressure vessel of a gas-fired low-pressure steam boiler is required to meet codes and standards published by:

(A) AGA

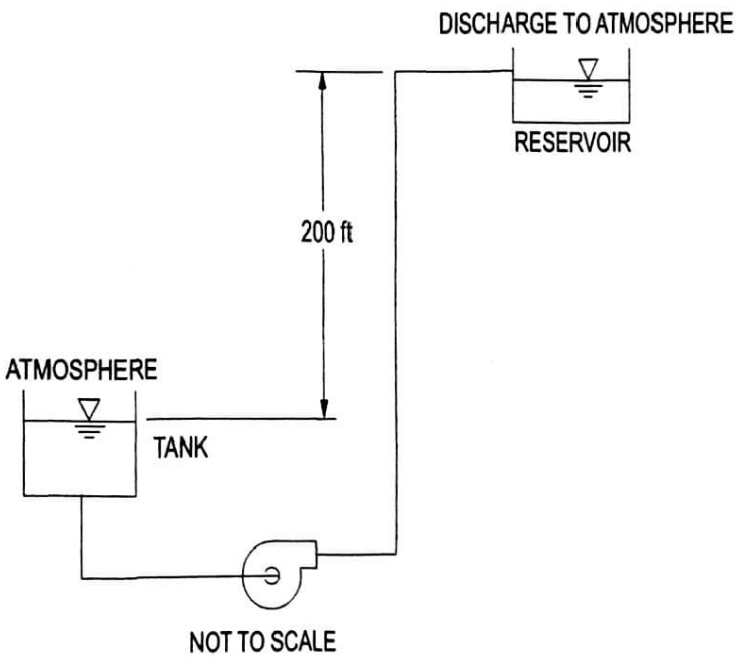
(B) UL

(C) ASME

(D) NFPA

515. The pumping and piping system shown is designed to transfer a fluid with a specific gravity of 1.32 from the lower atmospheric tank to the upper atmospheric reservoir. The total friction loss is 28 psi. The pump efficiency is 78%, and the flow rate is 5,000 gpm. The power (bhp) required by the pump is most nearly:

(A) 315
(B) 400
(C) 430
(D) 535



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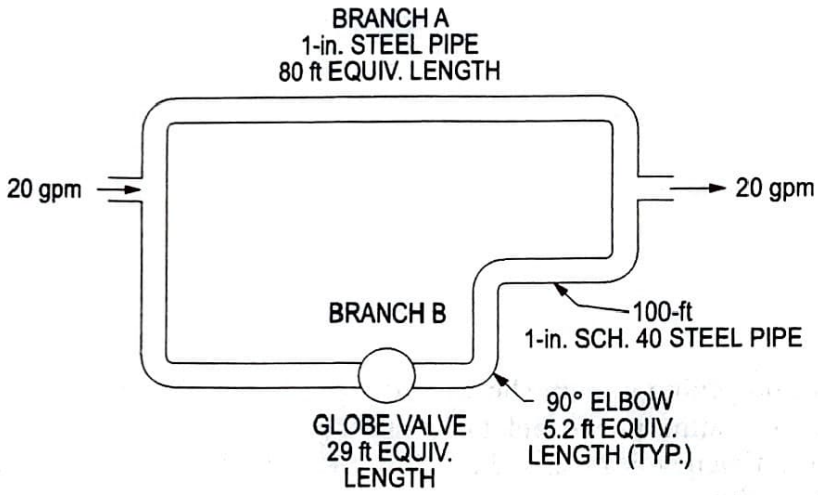
516. Water at 60°F and flowing at 20 gpm enters the parallel piping system shown in the figure. Branch A consists of Sch. 40 1-in. steel pipe with an equivalent length of 80 ft. Branch B consists of 100 ft of Sch. 40 1-in. steel pipe, four 90° elbows with equivalent lengths of 5.2 ft each, and a globe valve with an equivalent length of 29 ft. The flow rate (gpm) through Branch B is most nearly:

(A) 7
(B) 8
(C) 10
(D) 13



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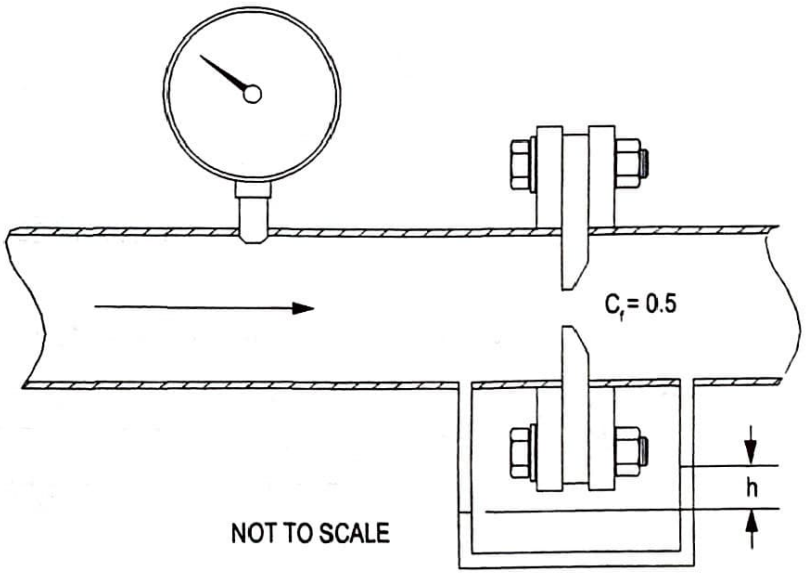
517. A steam condensate stream at 30 psig contains 3% vapor by weight. If the piping specification allows for 15 ft/sec liquid or 100 ft/sec vapor, the minimum nominal line size of Sch. 40 pipe (in.) that should be chosen for a flow of 90,000 lb/hr is most nearly:

(A) 3
(B) 4
(C) 6
(D) 8

518. The flow of water in a 10-in. Schedule 40 pipe is to be measured using a square-edged orifice meter with a diameter ratio of 0.5. Under the conditions listed below, the pressure drop across the orifice (lbf/in^2) is most nearly:

(A) 2.6
(B) 6.6
(C) 8.4
(D) 10.3

INLET CONDITIONS
Q = 1,200 gpm
T = 100°F
ρ = 62 lbm/ft^3
P_{static} = 20 psig



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519. A motor-driven pump draws water from a large reservoir as shown in the figure. The water level in the reservoir remains constant. The pump is required to move 300 gpm. The suction pipe is 4-in. Sch. 40 black steel, and the discharge pipe is 3-in. Sch. 40 black steel. The large reservoir contains water at 193°F and 10 psia. The pressure at the pump discharge must be 120 psig.

Water properties at 193°F:

Density, ρ	60.3 lbm/ft^3
Kinematic viscosity, υ	0.356×10^{-5} ft^2/sec
Vapor pressure	23.06 ft of fluid

Pipe sizes:

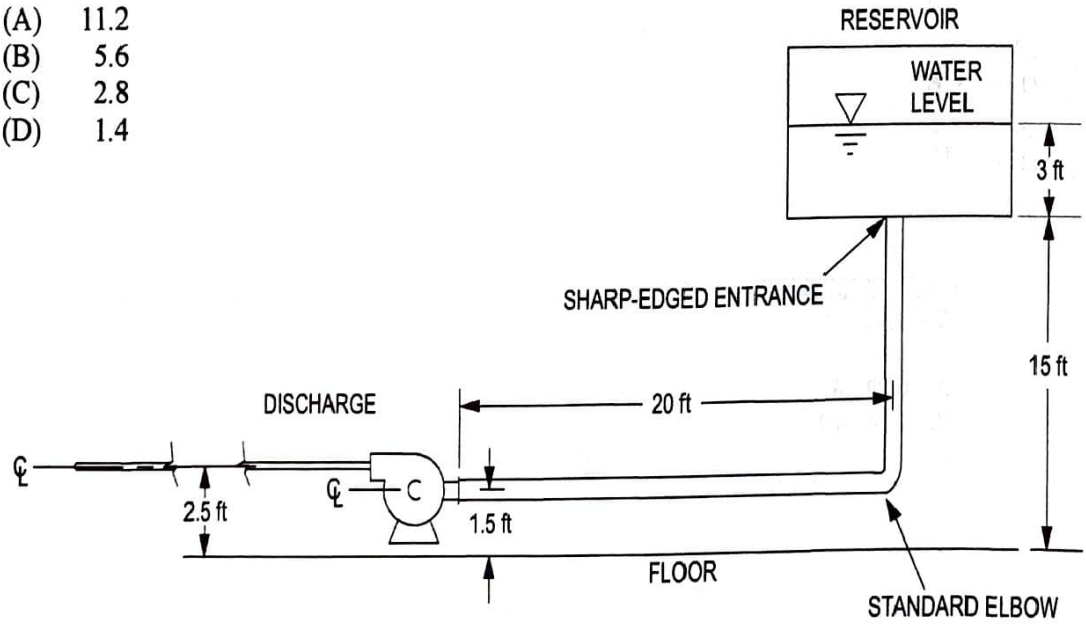
3 in. nominal is 3.068 in. I.D.
4 in. nominal is 4.026 in. I.D.

K values:

Entrance	0.5
Elbow	0.9

With a friction factor of 0.018, the line losses (ft) between the reservoir and pump, including entrance losses and friction losses through pipe, are most nearly:

(A) 11.2
(B) 5.6
(C) 2.8
(D) 1.4



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520. Water is flowing in a smooth pipe that has a diameter of 0.03 m. The water has a kinematic viscosity of 1×10^{-6} m^2/s and a Reynolds number of 1,800. The flow rate (m^3/hr) is most nearly:

(A) 4.2×10^{-5}
(B) 0.152
(C) 5.09
(D) 5.18

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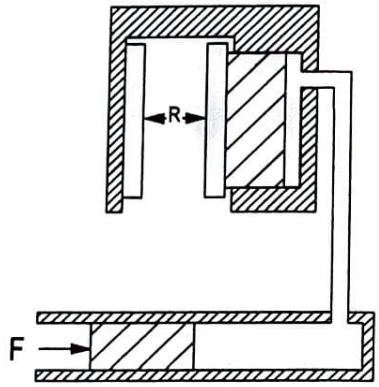
521. A motorcycle is equipped with a disc brake system consisting of a single-circuit master cylinder and caliper as shown. The caliper piston has a diameter of 30 mm. The master cylinder has a diameter of 20 mm. A reaction force R of 200 N is required at the caliper. The input force F (N) required at the master cylinder is most nearly:

(A) 90
(B) 130
(C) 200
(D) 450



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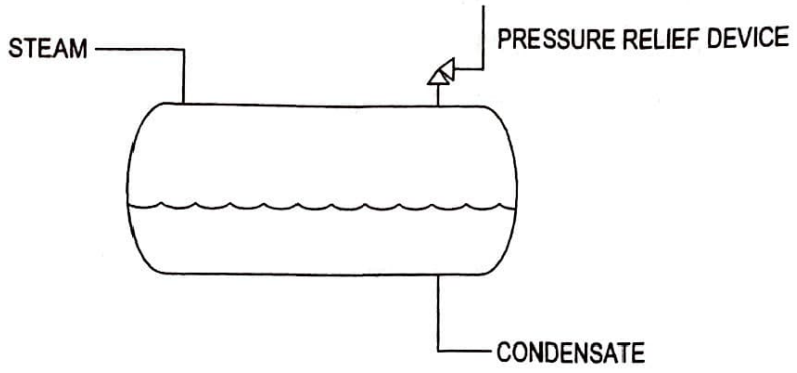
522. The pressure vessel shown operates at 90 psig. It has an overall dimension of 5-ft I.D. and is 11 ft long from head to head. The pressure vessel is an ASME Section VIII Division One Code Vessel and has a maximum allowable working pressure (MAWP) of 125 psig.

According to Paragraph UG-134 of the ASME code (provided), the maximum setting of the pressure relief device (psig) should be most nearly:

(A) 90
(B) 100
(C) 125
(D) 137.5



UG-134 PRESSURE SETTING OF PRESSURE RELIEF DEVICES

(*a*) When a single pressure relieving device is used, it shall be set to operate[55] at a pressure not exceeding the maximum allowable working pressure of the vessel. When the required capacity is provided in more than one pressure relieving device, only one device need be set at or below the maximum allowable working pressure, and the additional devices may be set to open at higher pressures but in no case at a pressure higher than 105% of the maximum allowable working pressure, except as provided in (b).

(*b*) Protective devices permitted in UG-125(c)(2) as protection against excessive pressure caused by exposure to fire or other sources of external heat shall be set to operate at a pressure not in excess of 110% of the maximum allowable working pressure of the vessel. If such a device is used to meet the requirements of both UG-125(c) and UG-125(c)(2), it shall be set to operate at not over the maximum allowable working pressure.

(*c*) The pressure at which any device is set to operate shall include the effects of static head and constant back pressure.

(*d*)(*1*) The set pressure tolerance for pressure relief valves shall not exceed ±2 psi for pressures up to and including 70 psi and 3% for pressures above 70 psi, except as covered in (d)(2).

(*2*) The set pressure tolerance of pressure relief valves which comply with UG-125(c)(3) shall be within –0%, +10%.

---

[55]*Set to operate* means the set pressure of a pressure relief valve or a spring loaded nonreclosing device; the bursting pressure of a rupture disk device; or, the breaking pressure of a breaking pin device.

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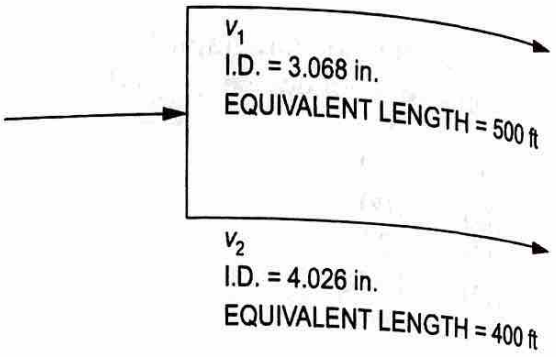
523. A horizontal piping system with both flows discharging to the atmosphere is shown in the figure. Both Fanning friction factors are approximately equal. The relationship between the velocities in Pipes 1 and 2 is most nearly:

(A) $v_2 = 0.78\ v_1$

(B) $v_2 = 1.15\ v_1$

(C) $v_2 = 1.28\ v_1$

(D) $v_2 = 1.64\ v_1$



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524. The following information is known about a new power plant.

Size	400 MW
Heat rate	11,010 Btu/kWh
Fuel	coal
Higher heating value of coal	14,100 Btu/lbm

Ultimate "as-fired" analysis (% weight) of coal	
Carbon	80.5%
Hydrogen	4.4%
Sulfur	1.9%
Oxygen	2.4%
Nitrogen	1.3%
Water	3.2%
Ash	6.3%
Total	100.0%

The mass (lbm CO_2/day) produced when the plant operates at full load for 24 hours and all carbon goes to carbon dioxide is most nearly:

(A) 1.646×10^6

(B) 6.034×10^6

(C) 22.13×10^6

(D) 39.29×10^6

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525. The cooling medium in a counterflow heat exchanger increases in temperature from 60°F to 110°F, while the process solution being cooled decreases from 150°F to 130°F. The logarithmic mean temperature difference (LMTD) for this counterflow heat exchanger is most nearly:

(A) 33°F
(B) 47°F
(C) 54°F
(D) 70°F

526. A counterflow heat exchanger with a surface area of 20 ft^2 condenses saturated H-134a vapor at 250 psia (T = 140°F, h = 120 Btu/lbm) to saturated liquid at 250 psia (h = 60 Btu/lbm). The inlet temperature of the cooling water is 60°F, and the outlet temperature of the cooling water is 75°F. The overall heat-transfer coefficient for the heat exchanger is 8 Btu/(hr-ft^2-°F). The rate (lbm/hr) at which the H-134a is condensed is most nearly:

(A) 20
(B) 40
(C) 100
(D) 200

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527. Steam at 900,000 lbm/hr exits a low-pressure steam turbine at 2.0 psia with 7% moisture content and a velocity of 300 fps. The required cross-sectional area (ft^2) is most nearly:

(A) 56.3
(B) 135
(C) 145
(D) 156

528. A shell-and-tube heat exchanger is to be designed to heat 10,000 lbm/hr of water from 40°F to 160°F. The heating medium is 37,000 lbm/hr of oil available at 256°F.

Property values: $c_{water} = 1.0$ Btu/(lbm-°F)
$c_{oil} = 0.54$ Btu/(lbm-°F)

The heat exchanger can be designed as parallel or counterflow. The ratio of the LMTD counterflow to LMTD parallel flow (i.e., $LMTD_{counterflow}/LMTD_{parallel\ flow}$) is most nearly:

(A) 1.25
(B) 1.15
(C) 1.05
(D) 1.0

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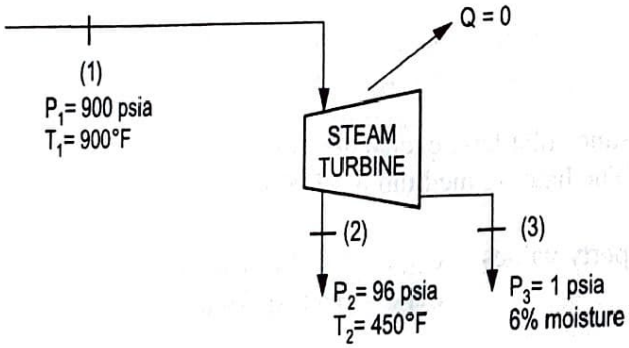
529. A 230-V ac, single-phase, 10-hp motor operates at 80% power factor and its rated load. If the efficiency of the motor is 65%, the current (amperes) drawn is most nearly:

(A) 12
(B) 17
(C) 40
(D) 62

530. The turbine efficiency from State 1 to State 2 is most nearly:

(A) 75%
(B) 79%
(C) 82%
(D) 87%

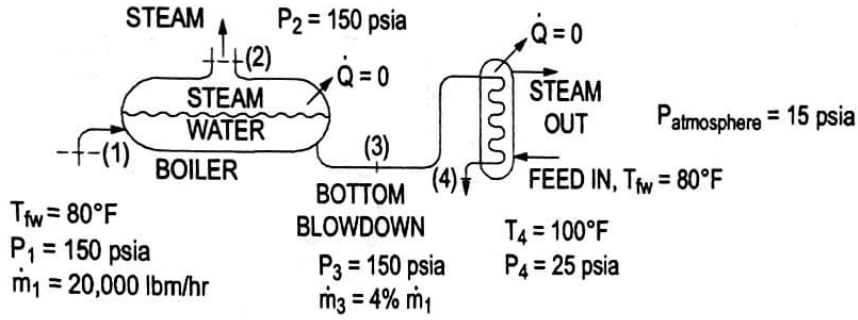


531. Steam enters an adiabatic turbine at 1,000 psia and 900°F and leaves at 2 psia. The turbine efficiency is 80%. The steady-state specific work (Btu/lbm) developed by the turbine is most nearly:

(A) 325
(B) 390
(C) 409
(D) 490

532. A boiler produces 150-psia saturated steam at 20,000 lbm/hr. Additionally, a 4% bottom blowdown is directed to a flash tank for auxiliary steam purposes. The maximum possible heat transfer (Btu/hr) in the heat exchanger is most nearly:

(A) 16,000
(B) 210,000
(C) 226,000
(D) 901,000



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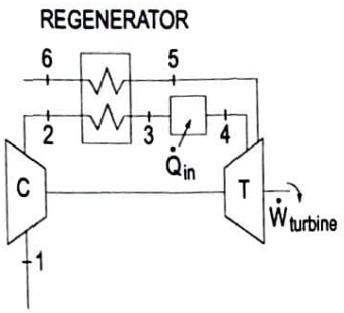
533. A regenerator with an effectiveness of 70% is added to a Brayton cycle. Assume a constant specific heat of 0.24 Btu/(lbm-°F), a pressure ratio of 4.5, ideal compression, and a turbine efficiency of 75%. Thermodynamic state values are given in the table. The thermal efficiency of the cycle is most nearly:

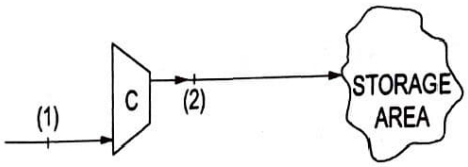
(A) 28%
(B) 48%
(C) 53%
(D) 75%



Station	T (°F)	P(psia)
1	80	14.7
2	370	
3		
4	2,680	66.2
5	1,746	
6	783	14.7

534. Air, an ideal gas, is compressed and stored in an underground area. Known data are given with the figure. The power (hp) required to compress the gas is most nearly:

(A) 29,900
(B) 34,200
(C) 40,300
(D) 45,800



$T_1 = 70°F$
$p_2/p_1 = 25$
$\eta_c = 88\%$
$\dot{m}_1 = 150$ lbm/sec

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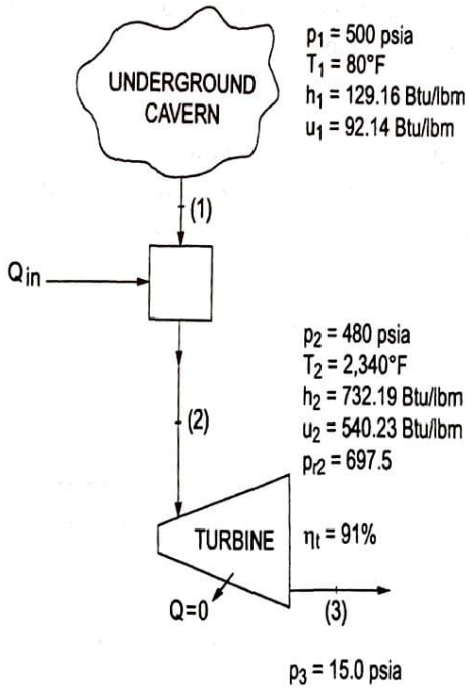
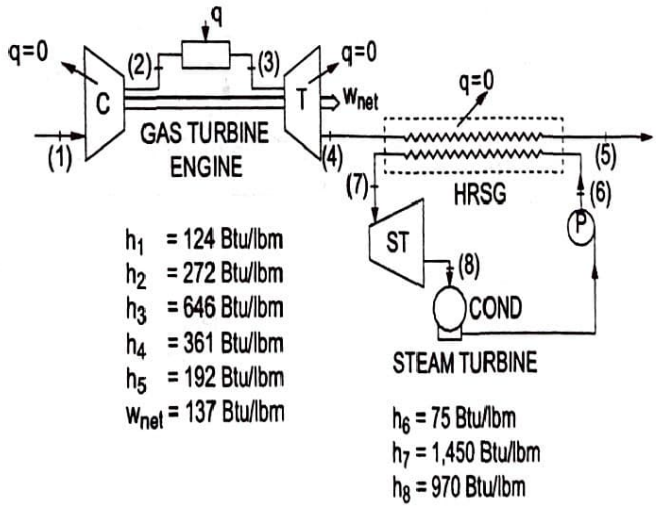
535. Air at 500 psia and 80°F is stored in an underground cavern. The air is extracted and heated, then expanded through a turbine. Known data are shown with the figure. Assuming air, with variable specific heats, is the working fluid throughout. The ratio of work produced 2→3 to heat added 1→2 is most nearly:

(A) 0.810
(B) 0.738
(C) 0.671
(D) 0.373



536. Known data for a gas turbine–steam turbine combined cycle are given with the figure. Neglecting pump work, the thermal efficiency of this combined cycle is most nearly:

(A) 42.2%
(B) 52.4%
(C) 62.9%
(D) 92.0%



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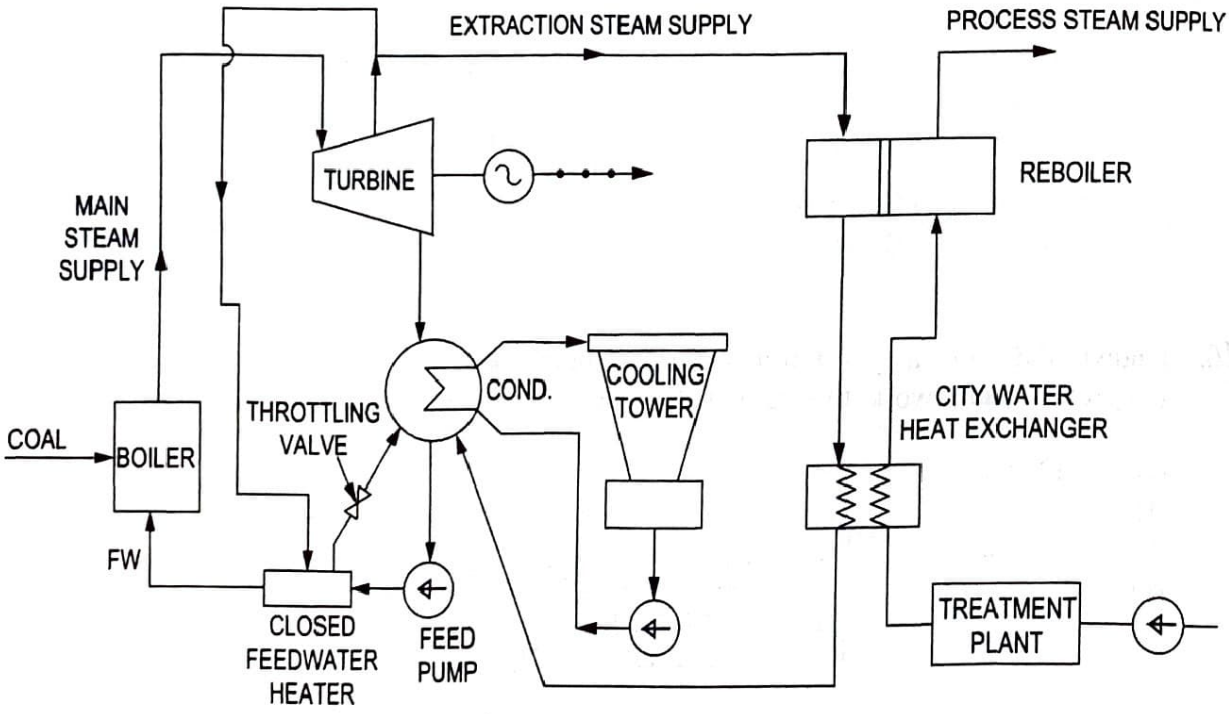
537. A cogeneration facility generates electricity and supplies steam to a chemical process plant, as shown in the figure. The following data are known:

Main steam supply	2,500 psia, 1,000°F
Feedwater supply to boiler, FW	3,000 psia, 400°F
Extraction steam supply	300 psia, 500°F

Extracted steam to closed feedwater heater leaves the heater as saturated liquid at 300 psia.

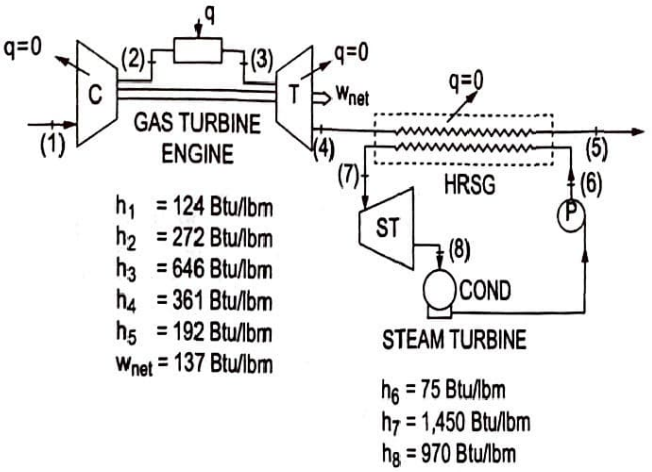
Extraction steam is used to heat feedwater in the closed feedwater heater. Condensate leaves the heater as saturated liquid. The ratio of steam (lbm of steam per lbm of feedwater) needed to heat the feedwater from 110°F to 400°F is most nearly:

(A) 0.10
(B) 0.22
(C) 0.34
(D) 0.62



538. Known data for a gas turbine–steam turbine combined cycle are given with the figure. If the work output of the gas turbine is 3.078×10^8 Btu/hr, the mass flow rate of steam (lbm/hr) is most nearly:

(A) 1,080,000
(B) 641,000
(C) 133,000
(D) 37



h_1 = 124 Btu/lbm
h_2 = 272 Btu/lbm
h_3 = 646 Btu/lbm
h_4 = 361 Btu/lbm
h_5 = 192 Btu/lbm
w_{net} = 137 Btu/lbm

h_6 = 75 Btu/lbm
h_7 = 1,450 Btu/lbm
h_8 = 970 Btu/lbm

539. Consideration is being given to building a new 500-MW power plant. The fuel that will be used is natural gas. Which of the following is **not** an advantage of a combined-cycle power plant over a conventional steam power plant?

(A) Allows use of a higher pressure in the steam cycle
(B) Reduced cooling water required
(C) Higher cycle thermal efficiency
(D) Reduced carbon dioxide emissions

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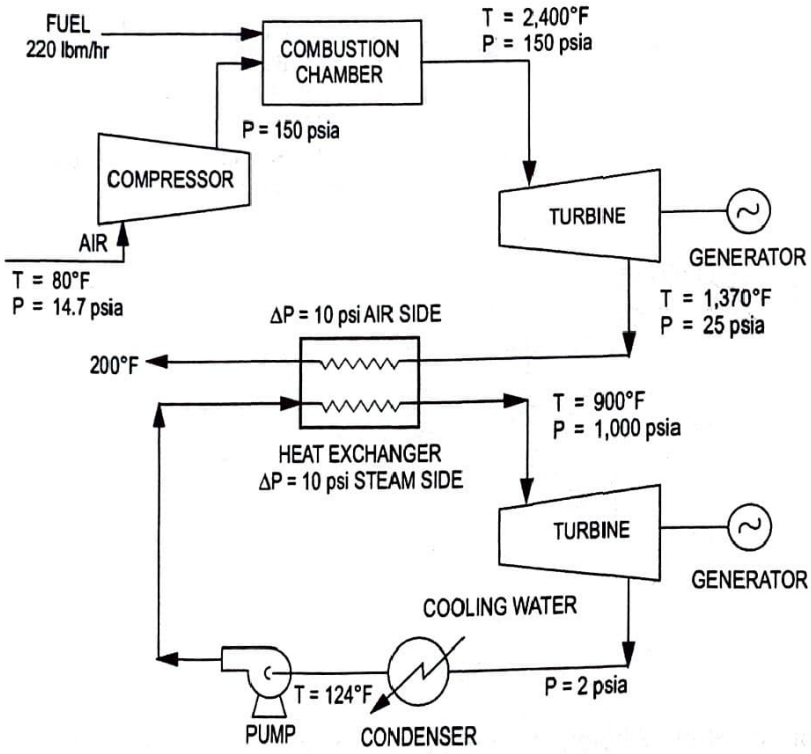
540. The system shown is a gas turbine cycle that exhausts to a steam cycle. Ambient air enters the compressor at 14.7 psia and 80°F. The steam turbine has an efficiency of 90%. If the k value is 1.4 and the compressor efficiency is 85%, the outlet temperature of the air from the compressor is most nearly:

(A) 512°F
(B) 589°F
(C) 645°F
(D) 678°F



This completes the afternoon session. Solutions begin on page 89.

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Answers to the Mechanical AM Practice Exam

Detailed solutions for each question begin on the next page.

101	C	**121**	C
102	A	**122**	C
103	D	**123**	C
104	C	**124**	B
105	C	**125**	D
106	A	**126**	A
107	C	**127**	B
108	B	**128**	B
109	B	**129**	D
110	B	**130**	C
111	C	**131**	C
112	B	**132**	A
113	D	**133**	A
114	C	**134**	D
115	B	**135**	D
116	C	**136**	A
117	B	**137**	C
118	C	**138**	C
119	D	**139**	D
120	D	**140**	A

101. Poisson's ratio is a measure of how a material deforms when acted upon by a force. It is applied in situations where the mechanical behavior of a machinery component is important.

THE CORRECT ANSWER IS: (C)

102. The coefficient of performance (COP) is a measure of energy efficiency of refrigeration systems.

THE CORRECT ANSWER IS: (A)

103. (A/P, 10%, 10) = 0.1627

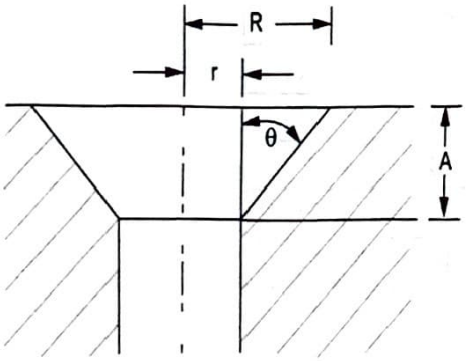
(A/F, 10%, 10) = 0.0627

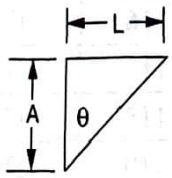
Annual operating cost = (300 days/yr)(16 hr/day)($2.50/hr) = $12,000

Total annual cost = $90,000(0.1627) – $10,000(0.0627) + $12,000 = $26,016

THE CORRECT ANSWER IS: (D)

104.





DETAIL OF OUTER
PART OF COUNTERSINK

$L = R - r = 0.39 - 0.156 = 0.234$ in.

$A = \frac{L}{\tan\theta} = \frac{0.234}{\tan 41°} = 0.269$ in.

R = Ø/2 = 0.78 in./2 = 0.39 in.

r = I.D./2 = 5/16 in./2 = 0.156 in.

θ = 82°/2 = 41°

THE CORRECT ANSWER IS: (C)

105. Given the maximum cost of \$36 per drum, the maximum amount of active ingredient is obtained by using as much as allowed of the cheaper formulation, and then topping off with the more costly formulation. At \$10/2 = \$5 per 100 units of active ingredient, Formulation 2 is less expensive. The maximum amount of Formulation 2 is 2 lb, which costs \$20 and gives 400 units of active ingredient. This leaves \$36 – \$20 = \$16 to spend on Formulation 1. This will buy 2 lb, which contains 2 lb × 100 units/lb = 200 units of active ingredient. This gives a total of 400 + 200 = 600 units, which is the maximum achievable within the constraints.

THE CORRECT ANSWER IS: (C)

106.

1. Determine minimum centerline of holes — $\text{℄} = 2.4 - 1.2 - 2(0.05) = 1.1$
2. Determine the maximum outside diameter of holes — $D_{max} = 0.9$
3. Determine minimum distance between surfaces — $1.1 - 0.9 = 0.2$

THE CORRECT ANSWER IS: (A)

107.

$$V = \frac{\dot{m}}{\rho A}$$

$$= \frac{50 \text{ lbm/sec}}{\left(51.4 \text{ lbm/ft}^3\right)\left(\frac{\pi}{4}\right)\left(\frac{4.026 \text{ in.}}{12 \text{ in./ft}}\right)^2}$$

$$= 11.0 \text{ ft/sec}$$

$$\text{Re} = \frac{VD\rho}{\mu}$$

$$= \frac{(11.0 \text{ ft/sec})\left(\frac{4.026 \text{ in.}}{12 \text{ in./ft}}\right)\left(51.4 \text{ lbm/ft}^3\right)}{0.000156 \text{ lbm/(ft-sec)}}$$

$$\text{Re} = 1.216 \times 10^6$$

For liquid metals, including sodium

$$\text{Nu} = \frac{hD}{K} = 5.0 + 0.025(\text{Re Pr})^{0.8}$$

From Incropera and Dewitt, *Fundamentals of Heat Transfer*, Pr = 0.0044

$$h = \frac{K}{D}\left[5.0 + (0.025)(\text{Re Pr})^{0.8}\right]$$

$$= \frac{[37.6 \text{ Btu/(hr-ft-°F)}]}{(4.026 \text{ in./12 in./ft})}\left[5.0 + (0.025)\left(1.216 \times 10^6\right)^{0.8}(0.0044)^{0.8}\right]$$

$$h = 3{,}253 \text{ Btu/(hr-ft}^2\text{-°F)}$$

THE CORRECT ANSWER IS: (C)

108. When both radiation and convection occur, the heat transfer is the sum of the two. If the tube is small compared to the room:

$$A = \pi DL = \pi(0.5\text{ ft})(20\text{ ft}) = 31.42\text{ ft}^2$$

$$Q = h\,A\,(T_s - T_a) + \sigma\,A\,\varepsilon\,[(T_s + 460)^4 - (T_a + 460)^4]$$

$$= [5\text{ Btu/(hr-ft}^2\text{-°F)}](31.42\text{ ft}^2)(450°\text{F} - 65°\text{F})$$

$$+ [0.1714 \times 10^{-8}\text{ Btu/(hr-ft}^2\text{-°R}^4\text{)}](31.42\text{ ft}^2)(0.5)[(450 + 460)^4\text{ °R}^4 - (65 + 460)^4\text{°R}^4]$$

$$= 76{,}900\text{ Btu/hr}$$

THE CORRECT ANSWER IS: (B)

109. $$Q = \frac{A\Delta T}{R_{total}}$$

Without shade: $$R_{total} = \frac{1}{h_{out}} + \frac{\Delta x}{K_{glass}} + \frac{1}{h_{in}}$$

$$= \frac{1}{4\text{ Btu/(hr-ft}^2\text{-°F)}} + \frac{(1/8\text{ in.})(1\text{ ft}/12\text{ in.})}{0.63\text{ Btu/(hr-ft-°F)}} + \frac{1}{1.46\text{ Btu/(hr-ft}^2\text{-°F)}}$$

$$= 0.9515\text{ hr-ft}^2\text{-°F/Btu}$$

With shade: $$R_{total} = R_{without\ shade} + R_{air\ gap} + R_{shade}$$

$$= 0.9515\,\frac{\text{hr-ft}^2\text{-°F}}{\text{Btu}} + 0.90\,\frac{\text{hr-ft}^2\text{-°F}}{\text{Btu}} + \frac{(1/8\text{ in.})(1\text{ ft}/12\text{ in.})}{0.03\text{ Btu/(hr-ft-°F)}}$$

$$= 2.1987\text{ hr-ft}^2\text{-°F/Btu}$$

$$\Delta Q = Q_{without\ shade} - Q_{shade}$$

$$= \frac{(200\text{ ft}^2)(70°\text{F})}{0.9515\,\frac{\text{hr-ft}^2\text{-°F}}{\text{Btu}}} - \frac{(200\text{ ft}^2)(70°\text{F})}{2.1987\,\frac{\text{hr-ft}^2\text{-°F}}{\text{Btu}}}$$

$$= 8{,}346\text{ Btu/hr}$$

THE CORRECT ANSWER IS: (B)

110. The heat transfer rate through the surface is given by

$\dot{Q} = h_{total} \times A_{surface} \times (T_{ambient} - T_{surface})$

Rearranging yields

$T_{surface} = T_{ambient} - \dot{Q}/(h_{total} \times A_{surface})$

where the heat dissipated (lost through the surface) is

$\dot{Q} = -15 \text{ W} = -51.18 \text{ Btu/hr}$

The heat-transfer coefficient is

$h_{total} = h_{rad} + h_{conv} = (1.00 + 1.25) \text{ Btu/(hr-ft}^2\text{-°F)}$

and the exposed surface area (assuming an adiabatic base mounting) is

$A_{surface} = (L \times W) + 2 \times (L \times h + W \times H) = 56 \text{ in}^2 = 0.39 \text{ ft}^2$

Solving for surface temperature

$T_{surface} = 75°\text{F} + (51.18 \text{ Btu/hr})/[2.25 \text{ Btu/(hr-ft}^2\text{-°F)} \times (0.39 \text{ ft}^2)] = 133°\text{F}$

THE CORRECT ANSWER IS: (B)

111. $q = hA\Delta T \quad \therefore \quad h = \dfrac{q}{A\Delta T}$

$$h = \frac{45{,}000 \text{ Btu}}{\text{hr}} \times \frac{1}{(100-75)°\text{F}} \times \frac{1}{400 \text{ ft}^2}$$

$$= 4.5 \text{ Btu}/\left(\text{hr-ft}^2\text{-°F}\right)$$

THE CORRECT ANSWER IS: (C)

112. $Q/A = \dfrac{\Delta T}{\dfrac{t}{k} + \dfrac{1}{h}}$

Substituting into the equation:

$$\left(500 \text{ W} \times \frac{3.413 \text{ Btu/hr}}{1 \text{ W}}\right)\left(\frac{1}{100 \text{ ft}^2}\right) = \frac{\Delta T}{\left(0.5 \text{ in.} \times \dfrac{1 \text{ ft}}{12 \text{ in.}}\right)\left(\dfrac{1 \text{ hr-ft-°F}}{0.03 \text{ Btu}}\right) + \left(\dfrac{1 \text{ hr-ft}^2\text{-°F}}{5 \text{ Btu}}\right)}$$

Solving for ΔT:

$\Delta T = 27°\text{F}$

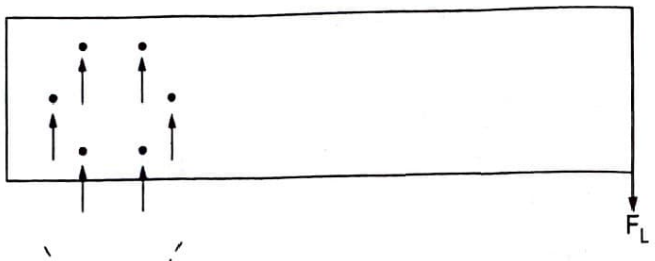
$T_{box} - 100°\text{F} = 27°\text{F}$

$T_{box} = 127°\text{F}$

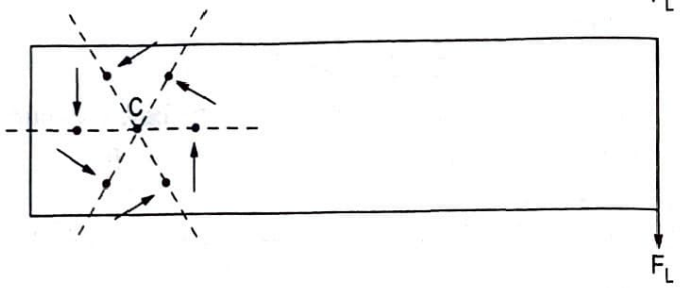
THE CORRECT ANSWER IS: (B)

113. Draw a free-body diagram.

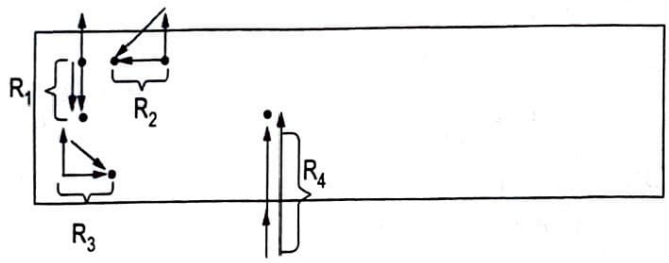
Forces due to load:



plus
Forces due to torsion:



Add vectors:



Bolt 4 has additive vectors and the greatest shear stress.

THE CORRECT ANSWER IS: (D)

114. $h_{mixture} = \frac{1}{2}(h_{water} + h_{steam}) = \frac{1}{2}(28.08 + 1{,}335.2)\text{Btu/lbm} = 681.64\ \text{Btu/lbm}$

$$681.64\ \text{Btu/lbm} = 180.1\ \text{Btu/lbm} + x(970.4\ \text{Btu/lbm}) \Rightarrow x = 0.516$$

THE CORRECT ANSWER IS: (C)

115. Flue gas mass for each component is number of moles × molecular weight:

$9\ CO_2$	$\Rightarrow (9)(44) =$	396
$9\ H_2O$	$\Rightarrow (9)(18) =$	162
$50.8\ N_2$	$\Rightarrow (50.8)(28) =$	1,422
	Total	1,980

$$\%\ H_2O = \frac{162}{1{,}980} \times 100 = 8.2\%$$

THE CORRECT ANSWER IS: (B)

116. At initial conditions of 600°F and 300 psia:

$h_i = 1{,}314.5$ Btu/lbm $\qquad s_i = 1.6266$ Btu/(lbm-°R)

Expansion process is constant entropy

i.e., $s_i = s_f$

Determine quality of steam at final condition

$$s_f = s_{liquid} + (x)s_{vapor}$$
$$1.6266 = 0.2009 + (x)1.6852$$
$$x = 0.846$$

Find h_f^t, theoretical enthalpy

$$h_f = h_{liquid} + (x)h_{vapor}$$
$$h_f = 109.37 + (0.846)(1.013.1)$$
$$h_f = 966.48 \text{ Btu/lbm}$$

Adiabatic efficiency:

$$\eta_{adiabatic} = \frac{\left(h_i - h_f^a\right)}{\left(h_i - h_f^t\right)}$$

$$0.8 = \frac{\left(1{,}314.5 - h_f^a\right)}{\left(1{,}314.5 - 966.48\right)}$$

$$h_f^a = 1{,}036.1 \text{ Btu/lb}$$

THE CORRECT ANSWER IS: (C)

117. Throttling is a constant enthalpy process.

Using the P-h diagram for R-134a, at 250 psi saturated liquid state, read $S_{initial}$ = 0.118 Btu/(lbm-°R). Move down line of constant enthalpy to 40 psia – entropy, S_{final} is 0.126 Btu/(lbm-°R).

Change $\Delta S = S_{final} - S_{initial} = 0.126 - 0.118 = 0.008$

THE CORRECT ANSWER IS: (B)

118. Stoichiometric mass of air

= (13.5 mole O_2 × 32 lbm/mole O_2) + (50.8 mole N_2 × 28 lbm/mole N_2)

= 1,854.4 lbm air

Stoichiometric mass of fuel (per mole of fuel)

= (9 × 12 lbm C) + (18 × 1 lbm H)

= 126 lbm fuel

With 12% excess air

Air/fuel ratio = 1.12 (1,854.4 lbm air)/126 lbm fuel

= 16.48 lbm air/lbm fuel

THE CORRECT ANSWER IS: (C)

119. The minimum required differential pressure is equal to the sum of the losses through a control valve and AHU. The 10 ft of water pressure loss through the AHU must be converted to psi.

Coil pressure drop = 10 ft × 0.433 = 4.33 psi

Adding this value to the design control valve loss of 5 psi yields 9.33 psi

THE CORRECT ANSWER IS: (D)

120. Work $= \dot{m} c_p \Delta T$

$c_{p\,air}$ = 0.24 Btu/(lbm-°R)

Work = [0.24 Btu/(lbm-°R)][(150 lbm/sec – 3 lbm/sec)(900°R – 460°R)+(3 lbm/sec)(630°R – 460°R)]

$$= (15{,}645.6 \text{ Btu/sec})\left(\frac{3{,}600 \text{ sec}}{\text{hr}}\right)\left(3.929 \times 10^{-4} \text{ hp/Btu/sec}\right)$$

= 22,130 hp

THE CORRECT ANSWER IS: (D)

121. Shaft horsepower = $\dot{W}_{hp}/\eta$

$\dot{W}_{hp} = \dot{m}w$

$= \dot{m}v\Delta P$

$\dot{m} = \rho\dot{V}$

$v = 1/\rho$

bhp $= \rho\dot{V}(1/\rho)\Delta P$

$= \dot{V}\Delta P$

$= (25 \text{ gal/min})(50 \text{ lbf/in}^2)(\text{ft}^3/7.48 \text{ gal})(\text{min}/60 \text{ sec})(144 \text{ in}^2/1 \text{ ft}^2)(\text{hp-sec}/550 \text{ lbf-ft})$

$\dot{W}_{hp} = 0.73$ hp

shaft hp $= 0.73 \text{ hp} / 0.7$

$= 1.04$ hp

THE CORRECT ANSWER IS: (C)

122. Since one pump can deliver 150 gpm at 60 ft head, four pumps in parallel are required to deliver 500 gpm.

THE CORRECT ANSWER IS: (C)

123. Using the pump affinity laws:

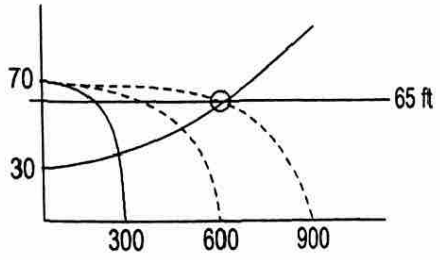
$$\frac{h_2}{h_1} = \left(\frac{n_2}{n_1}\right)^2$$

$h_2 = (60 \text{ ft})(1{,}000 \text{ rpm}/1{,}750 \text{ rpm})^2$

$h_2 = 19.60$ ft

THE CORRECT ANSWER IS: (C)

124. By inspection, after plotting a curve of the three pumps in parallel, the intersection with the system curve is at 65 ft.



THE CORRECT ANSWER IS: (B)

125. $\dot{w} = \dot{m}\,\Delta H$, where $\Delta H = 60$ ft

$\dot{m} = \rho\, Q$, where $\rho = 62.4$ lbm/ft^3

$$Q = \left(\frac{200\text{ gal}}{\text{min}}\right)\left(\frac{1\text{ ft}^3}{7.48\text{ gal}}\right) = 26.7\text{ ft}^3/\text{min}$$

$$\therefore \dot{m} = \left(\frac{62.4\text{ lbm}}{\text{ft}^3}\right)\left(\frac{26.7\text{ ft}^3}{\text{min}}\right) = 1{,}668\text{ lbm/min}$$

$$\therefore \dot{w} = \left(\frac{1{,}668\text{ lbm}}{\text{min}}\right)(60\text{ ft}) = 100{,}080\text{ ft-lbm/min}$$

$$\dot{w} = \left(\frac{100{,}080\text{ ft-lbm}}{\text{min}}\right)\left(\frac{\text{min-hp}}{33{,}000\text{ ft-lbm}}\right) = 3.03\text{ hp}$$

$$\dot{w} = \frac{3\text{ hp}}{(0.75)(0.83)} = 4.87\text{ hp} = 3.63\text{ kW}$$

$$\text{cost} = (3.63\text{ kW})(8{,}000\text{ hr})\left(\frac{\$0.06}{\text{kWh}}\right) = \$1{,}742$$

THE CORRECT ANSWER IS: (D)

126. For the constant, adiabatic, and isothermal flow of an incompressible fluid, a form of the Bernouilli equation is:

$$\frac{P_1}{\rho_1} + \frac{v_1^2}{2g_c} + \frac{h_1 g}{g_c} + h_{pump} = \frac{P_2}{\rho_2} + \frac{v_2^2}{2g_c} + \frac{h_2 g}{g_c} + h_f$$

where h_f = friction head

h_{pump} = pump head

ρ = density

P = pressure

v = linear velocity of flow (ft/sec)

g_c = gravitational constant

If the change in velocity is negligible, the equation reduces to:

$$h_{pump} = \frac{P_2}{\rho_2} - \frac{P_1}{\rho_1} + \frac{(h_2 - h_1)g}{g_c} + h_f$$

$$= \frac{(14.7 \text{ lb/in}^2)(144 \text{ in}^2/\text{ft}^2)}{(62.4 \text{ lb/ft}^3)1.2} - \frac{(74.7 \text{ lb/in}^2)(144 \text{ in}^2/\text{ft}^2)}{(62.4 \text{ lb/ft}^3)} + 225 \text{ ft} + 25 \text{ ft} = 105.88 \text{ ft}$$

Converting,

$$h_{pump} = \frac{105.88 \text{ ft } (50 \text{ gal/min})(0.13368 \text{ ft}^3/\text{gal})(62.4 \text{ lb/ft}^3)}{33{,}000 \text{ ft-lb/(min-hp)}} = 1.34 \text{ hp}$$

THE CORRECT ANSWER IS: (A)

127. $$m_{fraction} = \frac{m_{He}}{m_{total}} = 0.09091 = \frac{m_{He}}{m_{He} + 15{,}000 \text{ lbm}}$$

$$m_{He} = 1{,}500 \text{ lbm}$$

THE CORRECT ANSWER IS: (B)

128. **Compressor:**

$$\frac{T_{2,i}}{T_1} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

$$T_{2,i} = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k}$$

For air: k = 1.4

$$= (80°F + 460)(10)^{0.4/1.4}$$

$$T_{2,i} = 1{,}043°R$$

$$W_{comp} = \frac{\dot{m}c_p(T_{2,i} - T_1)}{\eta}$$

$c_p = 0.24$ Btu/(lbm-°R)

$$W_{comp} = \left[\left(100\frac{lbm}{sec}\right)\left(0.24\frac{Btu}{lbm\text{-}°R}\right)(1{,}043 - 540)°R\right]\left(\frac{60\ sec}{min}\right)\left(\frac{1}{0.85}\right)\left(\frac{hp\text{-}min}{42.44\ Btu}\right)$$

$W_{comp} = 20{,}062$ hp

Fan:

$$T_{2,i} = (540°R)(1.3)^{0.4/1.4}$$

$$= 582.0°R$$

$$W_{fan} = \left(400\frac{lbm}{sec}\right)\left(0.24\frac{Btu}{lbm\text{-}°R}\right)(582.0 - 540)°R\left(\frac{60\ sec}{min}\right)\left(\frac{1}{0.85}\right)\left(\frac{hp\text{-}min}{42.44\ Btu}\right)$$

$$= 6{,}711.78\ hp$$

$W_{total} = W_{comp} + W_{fan} = 20{,}062$ hp + 6,712 hp = 26,774 hp

THE CORRECT ANSWER IS: (B)

129. $\dot{m}RT = PAV$

$A = \dot{m}RT/(PV)$

$= [(150\ lbm/sec)(53.35\ ft\text{-}lbf/lbm\text{-}°R)(430°R)]/[(5.45\ lbf/in^2)(144\ in^2/ft^2)(600\ ft/sec)] = 7.30\ ft^2$

THE CORRECT ANSWER IS: (D)

130. $Q = AV$

$$A = \frac{\pi D^2}{4} = \left(\frac{\pi}{4}\right)(12\text{ in.})^2\left(\frac{1\text{ ft}}{12\text{ in.}}\right)^2 = 0.7854\text{ ft}^2$$

$$V = \sqrt{2gh}$$

$$h = (3\text{ in. } H_2O)\left(\frac{1\text{ ft}}{12\text{ in.}}\right)\frac{\left(62.4\text{ lbm water/ft}^3\right)}{\left(0.075\text{ lbm air/ft}^3\right)} = 208\text{ ft air}$$

$$Q = \left(0.7854\text{ ft}^2\right)\left(\sqrt{(2)(32.2\text{ ft/sec}^2)(208\text{ ft})}\right)\left(\frac{60\text{ sec}}{1\text{ min}}\right)$$

$$Q = 5{,}454\text{ ft}^3/\text{min}$$

THE CORRECT ANSWER IS: (C)

131. $\frac{Q_2}{Q_1} = \frac{n_2}{n_1} \rightarrow n_2 = \frac{Q_2}{Q_1} n_1$

$$n_2 = \frac{60}{50} \times 3{,}500 = 4{,}200\text{ rpm}$$

THE CORRECT ANSWER IS: (C)

132. Flow rate, $Q = 200$ gpm

Specific gravity, sp gr $= 0.7$

Total head, $h = 60$ ft

$$\text{HHP} = \frac{(h)(Q)(\text{sp gr})}{3{,}956} = \frac{(60)(200)(0.7)}{3{,}956} = 2.12\text{ hp}$$

THE CORRECT ANSWER IS: (A)

133. $\text{NPSHA} = h_a + h_s - h_f - h_{vap}$

$$h_f = h_a + h_s - \text{NPSHA} - h_{vap}$$

$$h_a = \frac{14.7 \times 144}{62.4} = 33.9\text{ ft}$$

$h_s = -18$ ft

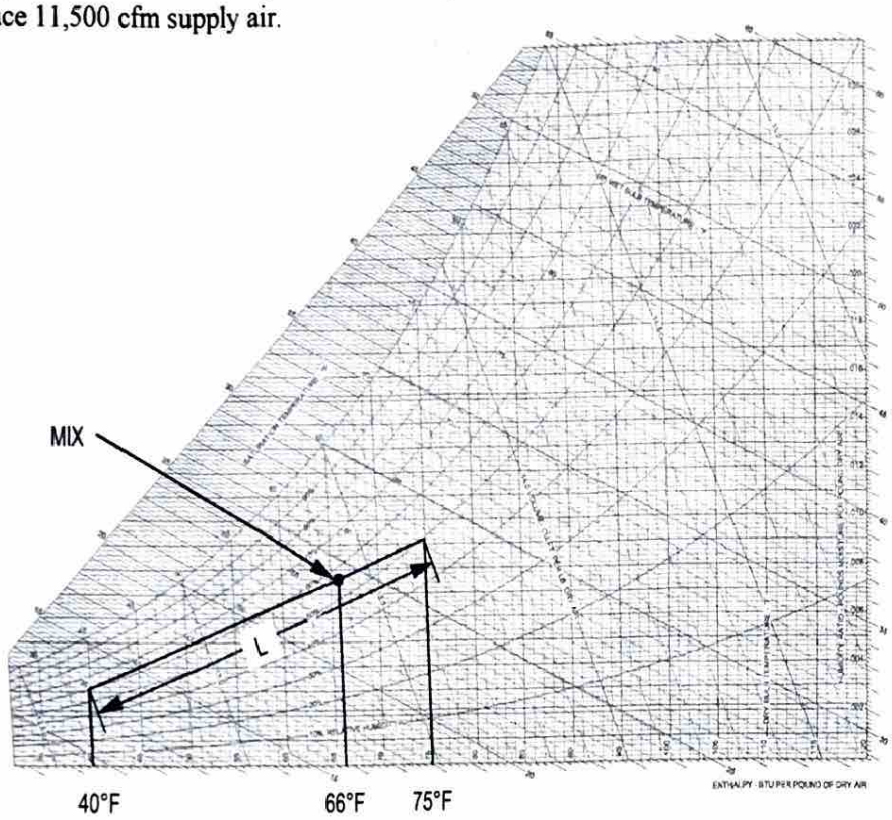
$h_{vap} = 2.19$ ft

$$h_f = 33.9 - 18 - 8 - 2.19$$

$$= 5.71\text{ ft}$$

THE CORRECT ANSWER IS: (A)

134. Mix 3,000 cfm of outside air (40°F and 60% rh) with 8,500 cfm of return air (75°F and 50% rh) to produce 11,500 cfm supply air.



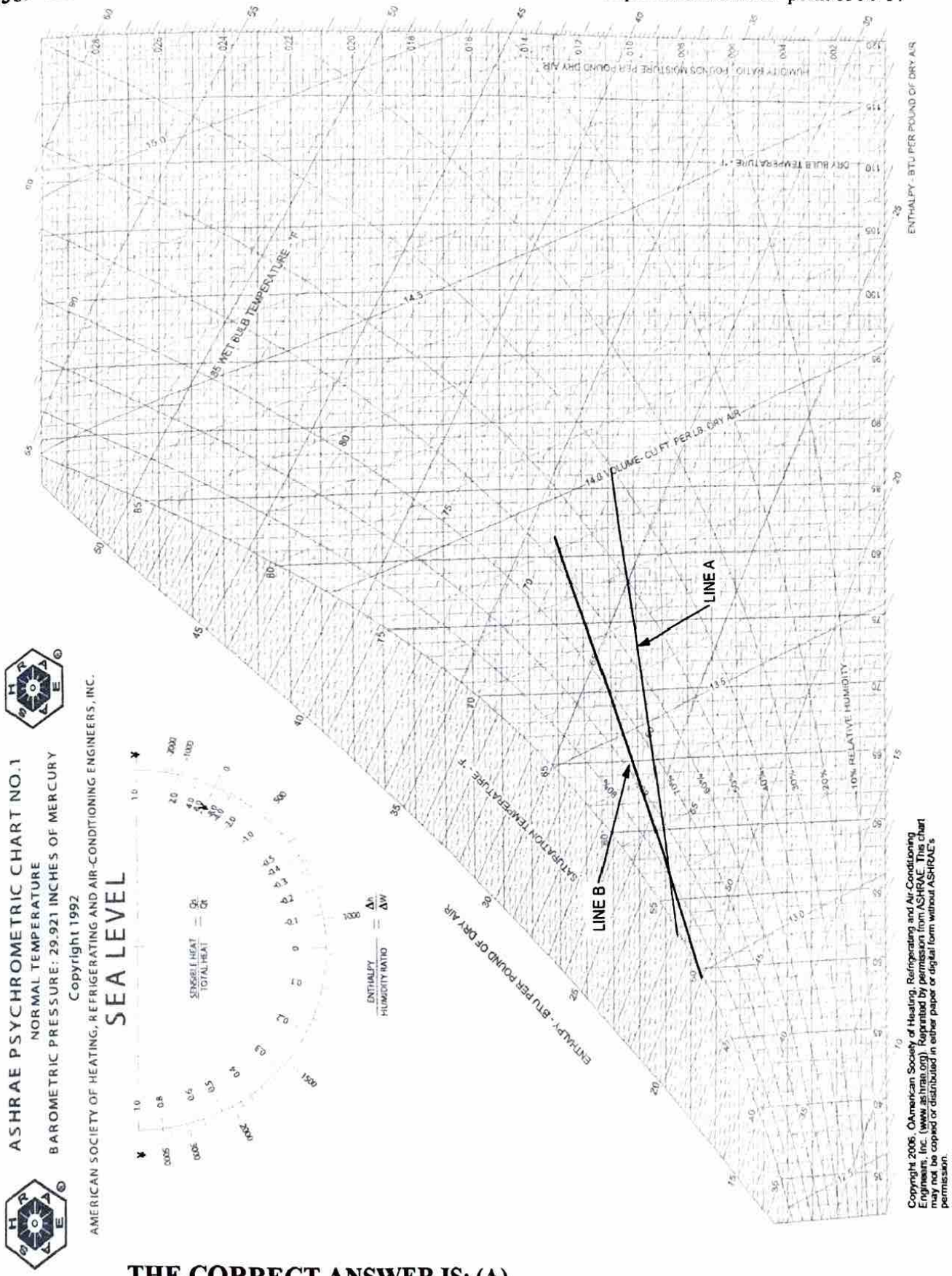
The mix is located at 3,000 cfm (L) /11,500 cfm = 0.261 (L) distance away from the room (return) air point along the line between the two states on the psychrometric chart. The dry-bulb temperature of the mix is 66°F.

THE CORRECT ANSWER IS: (D)

135. Fuel use increases in order to add additional energy to the steam. Therefore, CO_2 emissions will increase.

THE CORRECT ANSWER IS: (D)

136. Extend line B until it intersects with saturated line. The temperature is the dew point of 50°F.


LINE A
LINE B
ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
BAROMETRIC PRESSURE: 29.921 INCHES OF MERCURY
Copyright 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SEA LEVEL
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
WET BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
VOLUME - CU FT PER LB DRY AIR
10% RELATIVE HUMIDITY
SENSIBLE HEAT / TOTAL HEAT
ENTHALPY / HUMIDITY RATIO

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THE CORRECT ANSWER IS: (A)

137. $COP_{refrigerator} = \dfrac{Q_{absorbed}}{W_{compression}}$

1 refrigeration ton = 200 Btu/min = 12,000 Btu/hr = 3,517 W

$COP_{refrigerator} = \dfrac{3.517\ kW}{1\ kW} = 3.517$

THE CORRECT ANSWER IS: (C)

138. An expansion valve would be used for isenthalpic expansion of high-pressure saturated liquid refrigerant on this, the throttling leg.

THE CORRECT ANSWER IS: (C)

139. $q_{in} = h_1 - h_4 = 100.29 - 47.65 = 52.64$ Btu/lbm
$q_{out} = h_2 - h_3 = 129.78 - 47.65 = 82.13$ Btu/lbm
$w_c = h_2 - h_1 = 129.78 - 100.29 = 29.49$ Btu/lbm

$COP = \dfrac{q_{out}}{w_c} = \dfrac{82.13}{29.49} = 2.79$

THE CORRECT ANSWER IS: (D)

140. $\dot{m}_1 h_1 + \dot{m}_2 h_2 + \dot{m}_A h_A = \dot{m}_3 h_3 + \dot{m}_B h_B$

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

$\dot{m}_2 = \dot{m}_3 - \dot{m}_1$

$\dot{m}_1 h_1 + \dot{m}_3 h_2 - \dot{m}_1 h_2 - \dot{m}_3 h_3 = \dot{m}_A (h_B - h_A)$

$\dot{m}_1 (h_1 - h_2) + \dot{m}_3 (h_2 - h_3) = \dot{m}_A (h_B - h_A)$

$$\dot{m}_3 = \frac{\dot{m}_A (h_B - h_A) - \dot{m}_1 (h_1 - h_2)}{h_2 - h_3}$$

$h_1 = 236.15 + 0.85(933.9)$

$= 1,030$

$h_2 = 330.73$

$h_3 = 234.4$

$h_A = 168.07$

$h_B = 249.17$

$$\dot{m}_3 = \frac{1.2 \times 10^6 (249.17 - 168.07) - 1 \times 10^5 (1,030 - 330.73)}{330.73 - 234.4}$$

$= 284,366$ lbm/hr

THE CORRECT ANSWER IS: (A)

Answers to the Thermal and Fluids Systems PM Practice Exam

Detailed solutions for each question begin on the next page.

501	A	**521**	A
502	B	**522**	C
503	C	**523**	C
504	D	**524**	C
505	B	**525**	C
506	D	**526**	D
507	D	**527**	B
508	C	**528**	A
509	C	**529**	D
510	B	**530**	B
511	B	**531**	C
512	D	**532**	B
513	B	**533**	B
514	C	**534**	D
515	A	**535**	C
516	B	**536**	B
517	C	**537**	C
518	D	**538**	C
519	C	**539**	A
520	B	**540**	D

501. This problem can be solved by referring to a normal shock table, on which all normal shock factors depend only on the upstream Mach number (for a given k value). With an upstream Mach number of 4.5, the normal shock table gives the downstream Mach number of 0.4236.

THE CORRECT ANSWER IS: (A)

502. Flow in = flow out

$$A_1V_1 + A_2V_2 = A_3V_3$$

$$A_1V_1 = \left(\pi \times \frac{10^2}{4}\right) \times 12 \text{ in./sec}$$

$$= 942 \text{ in}^3/\text{sec}$$

$$A_2V_2 = \left(\pi \times \frac{5^2}{4}\right) \times 120 \text{ in./sec}$$

$$= 2{,}356 \text{ in}^3/\text{sec}$$

$$A_3V_3 = 942 + 2{,}356$$

$$= 3{,}298 \text{ in}^3/\text{sec}$$

$$V_3 = 3{,}298 / \left(\pi \times \frac{12^2}{4}\right)$$

$$= 29.16 \text{ in./sec}$$

$$= 2.43 \text{ fps}$$

THE CORRECT ANSWER IS: (B)

503. $$\text{Re} = \frac{VD}{\upsilon}$$

$$\text{Re} = \frac{(5 \text{ ft/sec})(0.33 \text{ ft})}{1.615 \times 10^{-5} \text{ ft}^2/\text{sec}} = 1.032 \times 10^5$$

THE CORRECT ANSWER IS: (C)

504. Using the pump similarity laws, power is directly proportional to the cube of the speed.

$$P_2 = P_1(S_2/S_1)^3$$

$$P_2 = 1{,}000 \text{ hp } (1{,}000 \text{ rpm}/1{,}750 \text{ rpm})^3$$

$$= 186 \text{ hp}$$

$$= 139 \text{ kW}$$

THE CORRECT ANSWER IS: (D)

505. $\Delta P = f\dfrac{L}{D}\rho\dfrac{V^2}{2g_c}$

$D = 1.063$ in.
$V = 5$ ft/sec
$f = 0.025$
$L = 100$ ft $= 1{,}200$ in.
$g_c = 32.2$ ft/sec^2

$$\Delta P = (0.025)\left(\frac{1{,}200 \text{ in.}}{1.063 \text{ in.}}\right)\left(\frac{62.4 \text{ lbm}}{\text{ft}^3}\right)\left(\frac{25 \text{ ft}^2}{\text{sec}^2}\right)\left(\frac{\text{sec}^2}{64.4 \text{ ft}}\right)$$

$$\Delta P = \left(\frac{684 \text{ lb}}{\text{ft}^2}\right)\left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right) = 4.75 \text{ lb/in}^2 = 4.75 \text{ psi}$$

THE CORRECT ANSWER IS: (B)

506. $P = \rho g L$

$$P_{psig} = P_{psia} - P_{atm}$$

$$= 19.4 \text{ psia} - 14.7 \text{ psia}$$

$$= 4.7 \text{ psig}$$

$$\rho = \frac{P}{gL} = 4.7\frac{\text{lbf}}{\text{in}^2} \times 144\frac{\text{in}^2}{\text{ft}^2} \times \frac{\text{sec}^2}{32.2 \text{ ft}} \times \frac{1}{35 \text{ in.}} \times \frac{32.2 \text{ lbm-ft}}{\text{lbf-sec}^2} \times \frac{12 \text{ in.}}{\text{ft}}$$

$$= 232.0 \text{ lbm}/\text{ft}^3$$

THE CORRECT ANSWER IS: (D)

507. Density of water, $\rho = 62.4$ lb/ft^3

Specific gravity, SG = 1.03

Velocity, $v = 30 \times 1.6878$ ft/sec

$= 50.634$ ft/sec

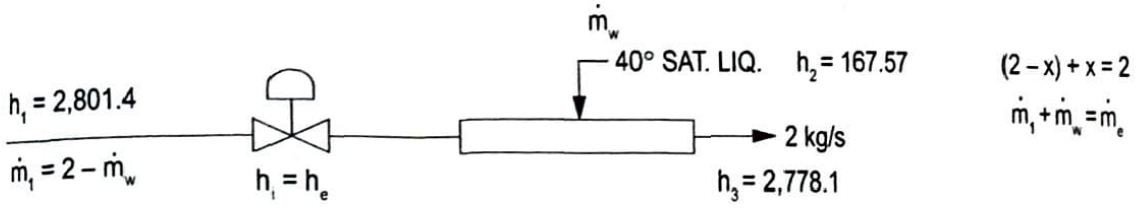
Depth, h = 165 ft

Stagnation pressure, $p = \rho \times g \times SG \times h + \dfrac{\rho \times SG \times v^2}{2}$

$= 91.428$ psi

THE CORRECT ANSWER IS: (D)

508.



From 1st Law:

$(2 - \dot{m}_w)\, h_1 + \dot{m}_w h_2 = 2\, h_3$

$(2 - \dot{m}_w)\,(2{,}801.4) + \dot{m}_w\,(167.57) = 2(2{,}778.1)$

$\dot{m}_w = 0.0177$ kg/s

THE CORRECT ANSWER IS: (C)

509. Water softener: 30,000 gallons per day = 15,000 gal. per 12 hr.
In 12 hours must reduce hardness from 26 to 2 grains per gallon. Capable of removing 20,000 grains/ft^3
Total removed in 12 hr:
15,000(24) = 360,000 grains

$$\text{Volume} = \frac{360{,}000 \text{ grains}}{20{,}000 \text{ grains/ft}^3} = 18 \text{ ft}^3$$

THE CORRECT ANSWER IS: (C)

510. Using steam tables:

$h_1 = 1{,}231.3$ Btu/lbm

$h_2 = 238.95$ Btu/lbm

$h_3 = 305.88$ Btu/lbm

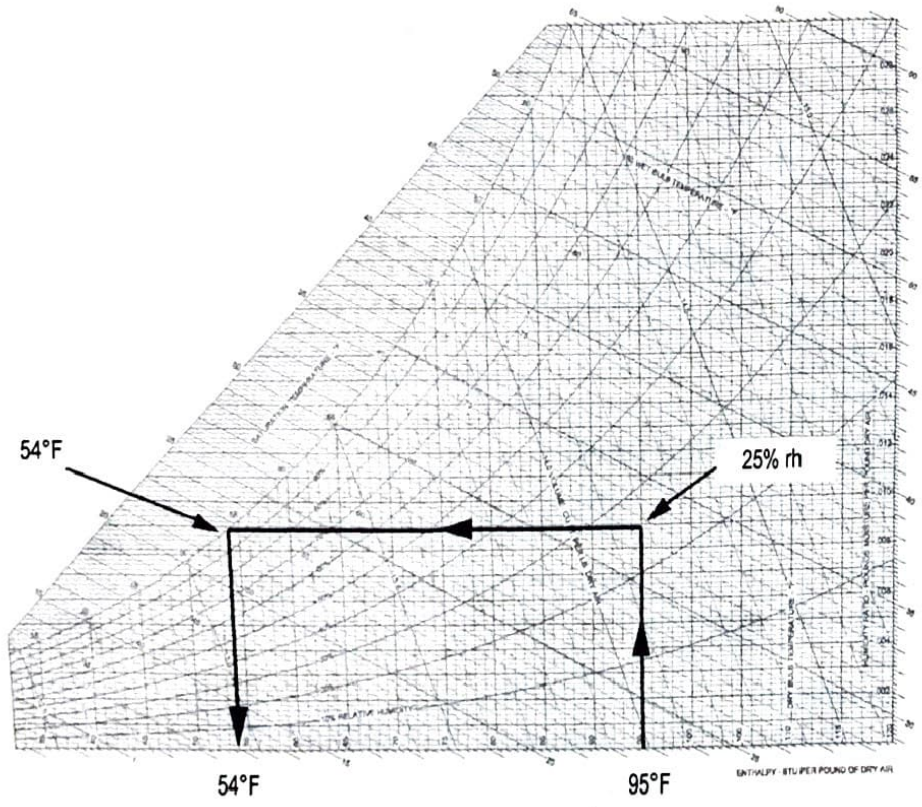
$h_4 = 375.12$ Btu/lbm

$60{,}000(375.12 - 238.95) = \dot{m}_1(1{,}231.3 - 305.9)$

$\dot{m}_1 = 8{,}825$ lbm/min

THE CORRECT ANSWER IS: (B)

511. Using a psychrometric chart, find the intersection of the 95°F line and the 25% rh line. Follow the constant humidity ratio line at 0.0088 lb H_2O/lb air horizontally to the saturation condition where the dew-point temperature is 54°F.



THE CORRECT ANSWER IS: (B)

512. Heat of vaporization of water = 970 Btu/lbm

Sensible heat load $Q_s = 3{,}000\ \text{W} \times \dfrac{3.41\ \text{Btu/hr}}{1\ \text{W}} = 10{,}230\ \text{Btu/hr}$

Latent heat load $Q_l = 5\ \text{lbm/hr} \times 970\ \text{Btu/lbm} = 4{,}850\ \text{Btu/hr}$

Total heat load $Q = Q_s + Q_l = 10{,}230\ \text{Btu/hr} + 4{,}850\ \text{Btu/hr}$

$= 15{,}080\ \text{Btu/hr}$

THE CORRECT ANSWER IS: (D)

513. Partial pressure (p) = P_{sat} at Temp × % rh

From steam table, P_{sat} at 80°F = 0.5073 psi

p(80°F, 60% rh) = (0.5073) (0.6) = 0.30 psi

Alternate solution:

Partial pressure = P_{sat} at dew point

From psychrometric chart at 80°F, 60% rh – dew point temperature is 65°F

From steam table, P_{sat} = 0.30 psi

THE CORRECT ANSWER IS: (B)

514. ASME

THE CORRECT ANSWER IS: (C)

515. Use $\text{bhp} = \dfrac{\text{Flow rate} \times \text{head} \times \text{sp gr}}{3{,}960\eta}$

Head = 200 ft (vertical lift) + friction head

$$\text{Friction head, ft} = \frac{\text{psi} \times 2.31}{\text{sp gr}} = \frac{28 \times 2.31}{1.32} = 49 \text{ ft}$$

Head = 200 + 49 = 249 ft

$$\text{bhp} = \frac{5{,}000 \times 249 \times 1.32}{3.960 \times 0.78} = 532 \text{ bhp}$$

THE CORRECT ANSWER IS: (A)

516. Darcy Weisbach equation: $h_f = \dfrac{f\,Lv^2}{2\,Dg}$

$L_{eq,\,B} = 100 \text{ ft} + (4 \times 5.2 \text{ ft}) + 29 \text{ ft} = 150 \text{ eq. ft}$

In this configuration, the pressure drop across Branch A is equal to the pressure drop across Branch B,

$$\text{so } h_{f,\,A} = h_{f,\,B} \Rightarrow \frac{f\,L_A V_A^2}{2\,Dg} = \frac{f\,L_B V_B^2}{2\,Dg} \Rightarrow V_A = V_B\sqrt{\frac{L_B}{L_A}} = V_B\sqrt{\frac{150 \text{ ft}}{80 \text{ ft}}} = 1.37\,V_B$$

Flow is proportional to V, thus $q_A = 1.37\,q_B$

$20 \text{ gpm} = q_A + q_B$

$20 \text{ gpm} = 1.37\,q_B + q_B$

$q_B = 8.4 \text{ gpm}$

THE CORRECT ANSWER IS: (B)

517. At 30 psig, from steam tables:

$V_v = 9.46\ ft^3/lb$ and $V_L = 0.0172\ ft^3/lb$

where V_v = volume of the vapor

V_L = volume of the liquid

Knowing that the flow is 3% vapor and 97% liquid by weight, calculate the volumetric flow rate for each phase:

$$Q_V = 0.03 \times 90{,}000\ lb/hr \times 9.46\ ft^3/lb = 25{,}542\ ft^3/hr = 7.095\ ft^3/sec$$

$$Q_L = 0.97 \times 90{,}000\ lb/hr \times 0.0172\ ft^3/lb = 1{,}501.56\ ft^3/hr = 0.4171\ ft^3/sec$$

where Q_v = volumetric flow rate of the vapor

Q_L = volumetric flow rate of the liquid

The minimum cross-sectional area for flow of each phase, based on the maximum velocities for the vapor and for the liquid, can be calculated as follows:

$$A_{V,\,min} = 7.095\ ft^3/sec \times \frac{1}{100\ ft/sec} = 0.07095\ ft^2$$

$$A_{L,\,min} = 0.4171\ ft^3/sec \times \frac{1}{15\ ft/sec} = 0.02781\ ft^2$$

where $A_{V,\,min}$ = minimum required area for flow of the vapor

$A_{L,\,min}$ = minimum required area for flow of the liquid

Adding the two, the minimum area A_{min} is:

$$A_{min} = 0.09876\ ft^2$$

The cross-sectional area for flow in a 4-in. Sch. 40 pipe is $0.0884\ ft^2$, which is too small.

The cross-sectional area for flow in a 6-in. Sch. 40 pipe is $0.2006\ ft^2$, which is larger than the minimum area.

THE CORRECT ANSWER IS: (C)

518. Pipe I.D. = 10.020 in.
Orifice diameter = (0.5)(10.020) = 5.010 in.

$$\text{Flow rate, } Q = C_f A_o \sqrt{\frac{2g\Delta P}{\rho}}$$

$$\frac{(1{,}200 \text{ gal/min})}{(60 \text{ sec/min})(7.48 \text{ gal/ft}^3)} =$$

$$(0.5)\left(\frac{\pi}{4}\right)(5.010 \text{ in.})^2(1 \text{ ft}/12 \text{ in.})^2 \sqrt{\frac{(2)(32.174 \text{ lbm-ft/lbf-sec}^2)(\Delta P \text{ lbf/in}^2)}{(62 \text{ lbm/ft}^3)(1 \text{ ft}^2/144 \text{ in}^2)}}$$

$$\Delta P = 10.2 \text{ lbf/in}^2$$

THE CORRECT ANSWER IS: (D)

519. $\text{Velocity} = \dfrac{\text{volumetric flow rate}}{\text{area}}$

$$V = \frac{(300 \text{ gal/min})}{(7.48 \text{ gal/ft}^3)(60 \text{ sec/min})\left(\frac{\pi}{4}\right)(4.026 \text{ in.})^2\left(\frac{1 \text{ ft}}{12 \text{ in.}}\right)^2}$$

$$= 7.56 \text{ ft/sec}$$

$$h_f = \left[K_{ent} + K_{elbow} + f\frac{L_e}{D}\right]\frac{V^2}{2g}$$

$$= \left[0.5 + 0.9 + (0.018)\frac{(33.5 \text{ ft})}{(4.026 \text{ in.})(1 \text{ ft}/12 \text{ in.})}\right]\frac{(7.56 \text{ ft/sec})^2}{(2)(32.2 \text{ ft/sec}^2)}$$

$$= 2.84 \text{ ft}$$

THE CORRECT ANSWER IS: (C)

520. $\text{Re} = \frac{VD}{\upsilon} = 1{,}800$

$D = 0.03 \text{ m}$

$\upsilon = 1\times10^{-6} \text{ m}^2/\text{s}$

$Q = AV$

$V = \frac{\text{Re}\,\upsilon}{D} = \frac{1{,}800\left(1\times10^{-6}\right)}{0.03} = 0.06 \text{ m/s}$

$A = \frac{\pi}{4}d^2$

$= \frac{\pi}{4}(0.03)^2$

$= 7.07\times10^{-4} \text{ m}^2$

$Q = 7.07\times10^{-4}(0.06) = 4.2\times10^{-5} \text{ m}^3/\text{s}$

Convert from seconds to hours

$Q = 4.2\times10^{-5}(3{,}600) = 0.152 \text{ m}^3/\text{hr}$

THE CORRECT ANSWER IS: (B)

521. P_c = pressure at caliper

P_{mc} = pressure at master cylinder

A_c = cross-sectional area of caliper

A_{mc} = cross-sectional area of master cylinder

F_{mc} = force at master cylinder

R_c = reaction at caliper cylinder

$A_{mc} = \pi r_{mc}^2 = (\pi)(10\text{ mm})^2 = \pi(100\text{ mm}^2)$

$= 314\text{ mm}^2$

$A_c = \pi r_c^2 = (\pi)(15\text{ mm})^2 = \pi(225\text{ mm}^2)$

$= 707\text{ mm}^2$

Hydraulic pressure is equal throughout the system. Therefore $P_{mc} = P_c$ where $P = F/A$. The forces at the two cylinders are proportional to the cross-sectional areas.

$$\frac{F_{mc}}{A_{mc}} = \frac{R_c}{A_c}$$

$$F_{mc} = \frac{R_c}{A_c} A_{mc} = \frac{(200\text{ N})(314\text{ mm}^2)}{(707\text{ mm}^2)} = 88\text{ N}$$

THE CORRECT ANSWER IS: (A)

522. In the ASME Section VIII, Div 1 Code, Subsection UG, Paragraph 135, the overpressurization device shall not be set higher than the MAWP (125 psig).

THE CORRECT ANSWER IS: (C)

523. The frictional head loss is given by the following equation:

$$F = 2f\frac{L}{D}\frac{v^2}{g_c}$$

where F = frictional head loss
f = Fanning friction factor
L = equivalent length of the pipe
D = diameter of the pipe
v = linear velocity of flow (ft/sec)
g_c = gravitational constant

Both streams go to atmosphere, so they have the same pressure drop. They come from the same source, so they have the same density. Thus the head loss is the same for both streams:

$$F_1 = F_2$$

$$2f\frac{L_1}{D_1}\frac{v_1^2}{g_c} = 2f\frac{L_2}{D_2}\frac{v_2^2}{g_c}$$

Rearranging and canceling common terms,

$$\frac{v_2^2}{v_1^2} = \frac{L_1}{L_2}\frac{D_2}{D_1}$$

or:

$$v_2 = \sqrt{\frac{L_1 D_2}{L_2 D_1}}\, v_1$$

Substituting the values given:

$$v_2 = \sqrt{\frac{500\text{ ft}(4.026\text{ in.})}{400\text{ ft}(3.068\text{ in.})}}\, v_1 = \sqrt{1.6403}\, v_1 = 1.281\, v_1$$

THE CORRECT ANSWER IS: (C)

524. All carbon is converted to CO_2

$$C \rightarrow CO_2$$

Mass of coal/day = power × heat rate × HHV

$$= (400 \times 10^3 \text{ kW})\left(11{,}010 \frac{\text{Btu}}{\text{kWh}} \times \frac{24 \text{ hr}}{\text{day}}\right)\left(\frac{\text{lbm}}{14{,}100 \text{ Btu}}\right)$$

$$= 7.5 \times 10^6 \text{ lbm/day}$$

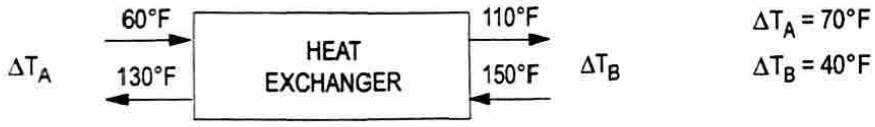
$$\text{Mass of } CO_2\text{/day} = \text{mass of coal/day} \times \%\text{ of carbon} \times \frac{\text{MW of } CO_2}{\text{MW of C}}$$

$$= 7.5 \times 10^6 \frac{\text{lbm}}{\text{day}} \times 0.805 \times \frac{44}{12}$$

$$= 22.13 \times 10^6 \text{ lbm } CO_2\text{/day}$$

THE CORRECT ANSWER IS: (C)

525.



$$\text{LMTD} = \frac{\Delta T_A - \Delta T_B}{\ln(\Delta T_A / \Delta T_B)}$$

$$= \frac{70 - 40}{\ln(70/40)} = 53.6°\text{F}$$

Alternate solution:

$$\text{LMTD} = \left[\frac{(\Delta T_A)^{1/3} + (\Delta T_B)^{1/3}}{2}\right]^3$$

$$= \frac{70^{1/3} + 40^{1/3}}{2} = 53.6°\text{F}$$

THE CORRECT ANSWER IS: (C)

526. Log mean temperature difference $LMTD = \dfrac{\Delta T_A - \Delta T_B}{\ln(\Delta T_A / \Delta T_B)}$

$$= \frac{(140°F - 75°F) - (140°F - 60°F)}{\ln\left(\dfrac{140°F - 75°F}{140°F - 60°F}\right)} = 72°F$$

Heat transfer $Q = UA(LMTD) = [8\ Btu/(hr\text{-}ft^2\text{-}°F)](20\ ft^2)(72°F) = 11{,}540\ Btu/hr$

$$Q = \dot{m}\Delta h \rightarrow \dot{m} = \frac{Q}{\Delta h} = \frac{Q}{h_{vapor} - h_{liquid}} = \frac{11{,}540\ Btu/hr}{120\ Btu/lb - 60\ Btu/lb} = 192\ lbm/hr$$

THE CORRECT ANSWER IS: (D)

527. $m = \rho AV = AV/v$

From steam tables

At 2 psia: $v_L = 0.016230\ ft^3/lbm$

$v_v = 173.72\ ft^3/lbm$

X = steam quality = 1 – moisture content

$= 1 - 0.07$

$= 0.93$

$v = v_L + X(v_V - v_L)$

$= 0.01623 + (0.93)(173.72 - 0.01623)$

$= 161.56\ ft^3/lbm$

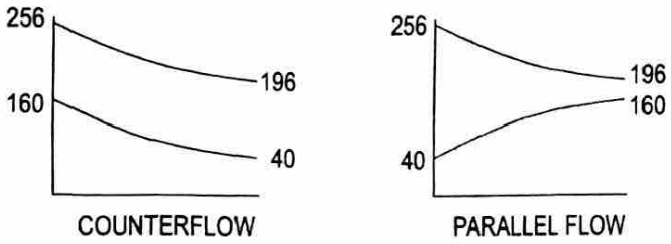
$m = AV/v$

$900{,}000\ lbm/hr = A\ (300\ ft/sec)(3{,}600\ sec/hr)/(161.56\ ft^3/lbm)$

$A = 135\ ft^2$

THE CORRECT ANSWER IS: (B)

528.



$$\left(\dot{m}c_p\Delta T\right)_{oil} = \left(\dot{m}c_p\Delta T\right)_{water}$$

$$\dot{m}_{oil}c_{p\,oil}\left(T_{oil\,in} - T_{oil\,out}\right) = \dot{m}_w c_{p\,w}\left(T_{w\,out} - T_{w\,in}\right)$$

$$(37{,}000\ \text{lbm/hr})[0.54\ \text{Btu/(lbm-°F)}](256\,°\text{F} - T_{oil\,out})$$
$$= (10{,}000\ \text{lbm/hr})[1\ \text{Btu/(lbm-°F)}](160°\text{F} - 40°\text{F})$$

$$T_{oil\,out} = 196°\text{F}$$

$$\text{LMTD} = \frac{\Delta T_A - \Delta T_B}{\ln(\Delta T_A/\Delta T_B)}$$

$\text{LMTD}_{counterflow}$: $\Delta T_A = (256 - 160) = 96°\text{F}$
$\Delta T_B = (196 - 40) = 156°\text{F}$

$\text{LMTD}_{parallel\ flow}$: $\Delta T_A = (256 - 40) = 216°\text{F}$
$\Delta T_B = (196 - 160) = 36°\text{F}$

$$\text{ratio} = \frac{\text{LMTD}_{counterflow}}{\text{LMTD}_{parrallel\ flow}}$$

$$= \frac{(96-156)/\ln(96/156)}{(216-36)/\ln(216/36)}$$

$$= 1.23$$

THE CORRECT ANSWER IS: (A)

529. $I = \dfrac{(sf)(P)}{(V)\,\eta\,(pf)}$

$I = \dfrac{(1.0)(7,457)}{(230)(0.65)(0.80)} = 62.3\text{ A}$

Service factor, sf = 1.0 at full load
Power, P = 10 hp × 0.7457 kW/hp × 1,000 W/kW
= 7,457 W
Voltage, V = 230 V
Efficiency, η = 0.65
Power factor, pf = 0.80

THE CORRECT ANSWER IS: (D)

530. (1) $P_1 = 900$ psia
$T_1 = 900°F$
From superheated steam properties
$h_1 = 1{,}452.3$ Btu/lbm
$s_1 = 1.6262$ Btu/(lbm-°R)

(2) $P_2 = 96$ psia
$T_2 = 450°F$
From superheated steam properties
$h_2 = 1{,}254.38$ Btu/lbm

For isentropic expansion to 96 psia
$s_2' = 1.6262$ Btu/(lbm-°R)
$h_2' = 1{,}201.24$ Btu/lbm

efficiency, $\eta = (h_1 - h_2)/(h_1 - h_2')$

$$= \frac{1{,}452.3\text{ Btu/lbm} - 1{,}254.38\text{ Btu/lbm}}{1{,}452.3\text{ Btu/lbm} - 1{,}201.24\text{ Btu/lbm}}$$

$= 0.79$ or 79%

THE CORRECT ANSWER IS: (B)

531. $\eta = \dfrac{h_1 - h_2}{h_1 - h_{2,i}} = \dfrac{w_t}{w_{t,i}}$

From steam tables:

h_1 (T = 900°F, P = 1,000 psia) = 1,448.1 Btu/lbm

s_1 = 1.612 Btu/(lbm-°R)

For isentropic process:

$s_2 = s_1 = 1.612$ Btu/(lbm-°R)

At P_2 = 2 psia

$$x_2 = \frac{s_2 - s_f}{s_{fg}}$$

$$= \frac{1.612 - 0.175}{1.7448}$$

$$= 82.17\%$$

$$h_{2,i} = h_f + x_2 h_{fg}$$

$$= 94.02 \text{ Btu/lbm} + 0.8217 \times 1{,}022.1 \text{ Btu/lbm}$$

$$= 933.89 \text{ Btu/lbm}$$

$$w_t = \eta\left(h_1 - h_{2,i}\right)$$

$$= 0.8\left(1{,}448.1 - 933.89\right) \text{Btu/lbm}$$

$$= 411.4 \text{ Btu/lbm}$$

THE CORRECT ANSWER IS: (C)

532. 20,000 lbm/hr × 0.04 = 800 lbm/hr blowdown

From steam tables:

h_3 = 330.7 Btu/lbm (150 psi, x = 0)

h_4 = 68 Btu/lbm (25 psi, T = 100°F)

For flash tank:

$$\dot{Q} = \dot{m}\left(h_3 - h_4\right)$$

$$= 800 \text{ lbm/hr}\left(330.7 - 68\right) \text{Btu/lbm} = 210{,}160 \text{ Btu/hr}$$

THE CORRECT ANSWER IS: (B)

533. Find T_3 given constant specific heat:

$$\eta_{regen.} = \frac{T_3 - T_2}{T_5 - T_2}$$

Solving for T_3:

$$T_3 = T_2 + \eta_{regen.}(T_5 - T_2)$$
$$= 370°F + 0.7(1{,}746°F - 370°F)$$
$$= 1{,}333°F$$

Solve for thermal efficiency given constant mass flow and specific heat:

$$\eta_{th} = \frac{\dot{W}_{out} - \dot{W}_{in}}{\dot{Q}_{in}} = \frac{(T_4 - T_5) - (T_2 - T_1)}{(T_4 - T_3)}$$
$$= \frac{(2{,}680°F - 1{,}746°F) - (370°F - 80°F)}{(2{,}680°F - 1{,}333°F)}$$
$$= 0.48$$

THE CORRECT ANSWER IS: (B)

534. $T_1 = 70 + 460 = 530°R$

Use gas tables

$h_1 = 126.76$ Btu/lbm

Relative pressure, $P_{r,1}$

$P_{r,1} = 1.2927$

$$P_{r,2i} = P_{r,1}\left[\frac{P_2}{P_1}\right] = 1.2927[25] = 32.318$$

$$h_{2i} = 316.79 \text{ Btu/lbm}$$

$$w_{c,a} = \frac{w_{c,i}}{\eta_c} = \frac{[h_{2i} - h_1]}{\eta_c} = \frac{316.79 - 126.76}{0.88} = 215.98 \text{ Btu/lbm}$$

$$\dot{w}_c = \dot{m}\, w_{c,i} = \left(\frac{150 \text{ lbm}}{\text{sec}}\right)\left(\frac{3{,}600 \text{ sec}}{\text{hr}}\right)\left(\frac{215.9 \text{ Btu}}{\text{lbm}}\right)\left(\frac{\text{hp-hr}}{2{,}545 \text{ Btu}}\right)$$
$$= 45{,}810 \text{ hp}$$

THE CORRECT ANSWER IS: (D)

535. $q_{1-2} = 732.19 - 129.16 = 603.03$ Btu/lbm

$$pr_3 = pr_2 \frac{p_3}{p_2}$$

$$= 697.4\left(\frac{15}{480}\right)$$

$$= 21.8 \text{ psi}$$

From air tables, find h_{3i} corresponding to pr_3

$h_{3i} = 281.14$ Btu/lbm

$$\frac{\dot{w}_{2-3}}{q_{1-2}} = \frac{0.91(732.19 - 281.14)}{603.03}$$

$$= 0.68$$

THE CORRECT ANSWER IS: (C)

536. $\dot{m}_1(h_4 - h_5) = \dot{m}_6(h_7 - h_6)$

$(1)(361 - 192) = \dot{m}_6(1,450 - 75)$

$\dot{m}_6 = 0.123$ lbm/sec

$$\eta_{th} = \frac{\dot{w}_{net}}{q_{in}} = \frac{(1)(137) + (0.123)(1,450 - 970)}{(1)(646 - 272)}$$

$$= \frac{137 + 59}{374} = 52.4\%$$

THE CORRECT ANSWER IS: (B)

537. Consider the feedwater heater.

$h_a\,(T = 500°F,\ P = 300\ \text{psia}) = 1,257.5\ \text{Btu/lbm}$

$h_b = h_f\,(P = 300\ \text{psia}) = 394.1\ \text{Btu/lbm}$

$h_c = 378.3\ \text{Btu/lbm}$

$h_d = 85.8\ \text{Btu/lbm}$

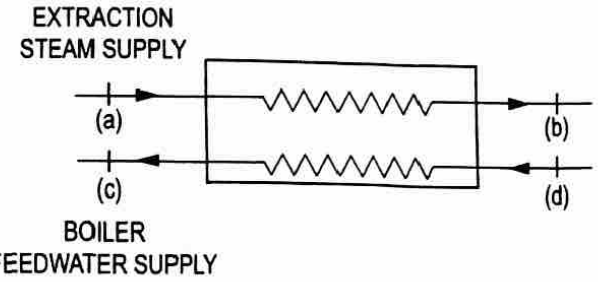
Energy balance:

$$m_{steam}\,(h_a - h_b) = m_{feedwater}\,(h_c - h_d)$$

$$\frac{m_{steam}}{m_{feedwater}} = \frac{(h_c - h_d)}{(h_a - h_b)}$$

$$= \frac{378.3 - 85.8}{1,257.5 - 394.1}$$

$$= 0.34\,\frac{\text{lbm of steam}}{\text{lbm of feedwater}}$$



THE CORRECT ANSWER IS: (C)

538. $W_T = \dot{m}_4\,(h_3 - h_4)$

$3.078 \times 10^8 = \dot{m}_1(646 - 361)$

$\dot{m}_1 = 1.08 \times 10^6\ \text{lbm/hr}$

$\dot{m}_4\,(h_4 - h_5) = \dot{m}_7\,(h_7 - h_6)$

$1.08 \times 10^6\ \text{lbm/hr}\,(361 - 192) = \dot{m}_7\,(1,450 - 75)$

$\dot{m}_7 = 132,742\ \text{lbm/hr}$

THE CORRECT ANSWER IS: (C)

539. Pressures are lower not higher due to the lower temperature at the exit from the gas turbine than can be achieved in a conventional steam power plant.

THE CORRECT ANSWER IS: (A)

540. $T_{2i} = T_1\left[\frac{p_2}{p_1}\right]^{\frac{k-1}{k}} = 540\left[\frac{150}{14.7}\right]^{\frac{0.4}{1.4}} = 1,049^\circ R = 589^\circ F$

$$\eta_{comp} = \frac{w_s}{w_a} = \frac{T_{2i} - T_1}{T_{2a} - T_1} = \frac{1,049 - 540}{T_{2a} - 540} = 0.85$$

$T_{2a} = 678^\circ F$

THE CORRECT ANSWER IS: (D)